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EDITORIAL.

ITEMS AND NOVELTIES.

A Self-Feeding Hand-Drill.—Manufactured by C. Van Haagen & Co., Philadelphia.—We present herewith external and sectional illustrations of a tool of this description, manufactured by the above-named firm.

Upon turning the horizontal shaft, the drill is caused to rotate by the bevel wheels shown in the centre of the stock.

On the horizontal shaft is a spur-wheel, A, which communicates rotary motion to a worm and wheel, C, the latter secured to the feeding-screw. The feeding-screw, however, thus set in motion operates in a non-rotating box.

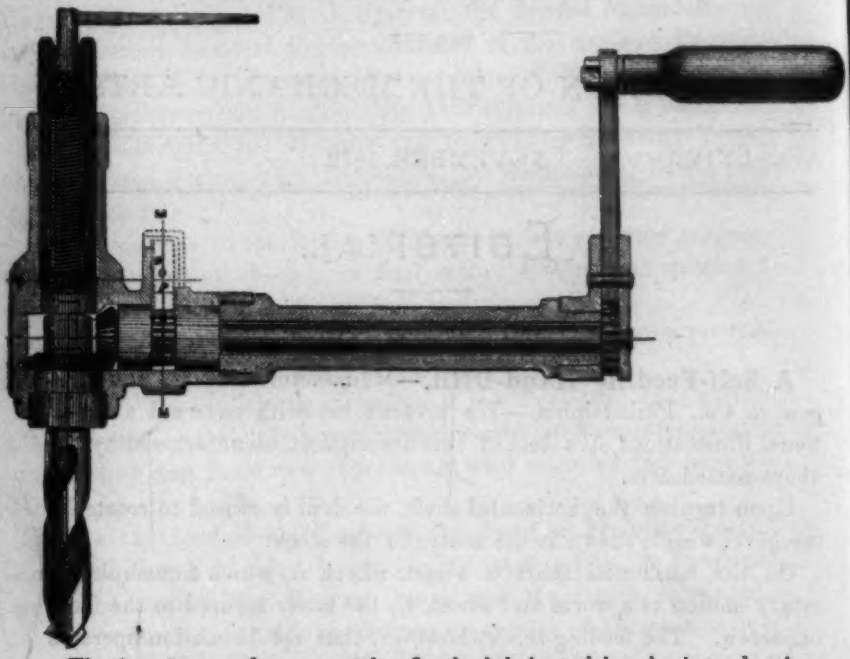
The motion of the screw will, therefore, produce a vertical movement of the box, or should this be brought against any firmly resisting object, the drill will be given a forward movement, or, more correctly, this movement will be given to the whole tool, and the operation of drilling thus performed.

For the purpose of effecting directly a more rapid vertical movement of the drill, a second box is placed within the first, which can be turned upon the feed-screw by the key, thus enabling the operator

easily to regulate the distance between the resting-point of the tool and the work.

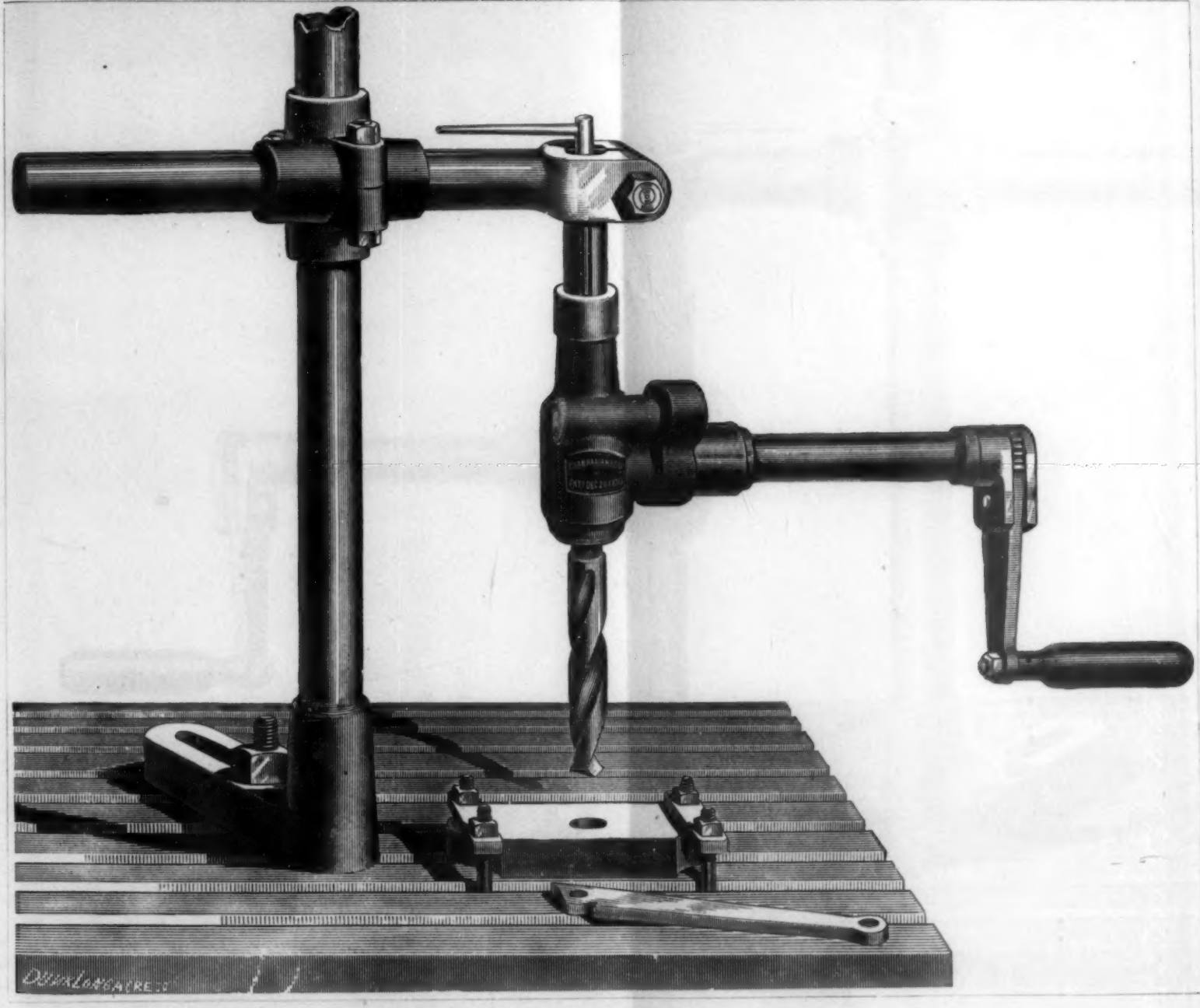
In the cuts, the letters A and B mark the place of the two spur-wheels, and the worm which engages with the worm-wheel, C, is visible upon the shaft of the wheel, B. To the worm-wheel, C, the feed-screw is attached. The key which rotates the inner box is finally seen in position.

This ingenious hand-drill combines two excellent features—continuous movement and automatic feed. It is light, strong and compact, the working parts being made of steel and well fitted.



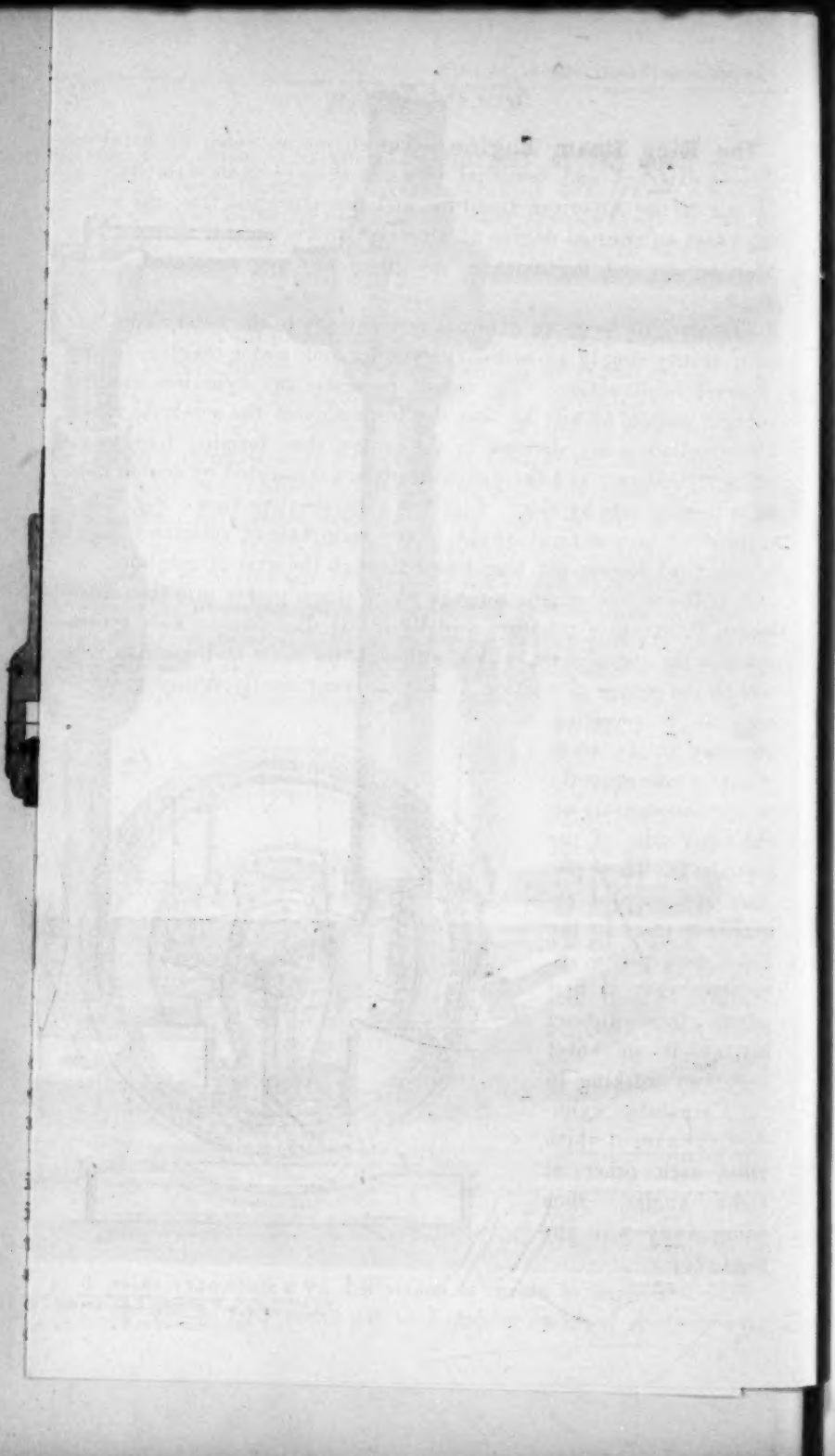
The bearing surfaces may be freely lubricated by the introduction of oil from one point on the exterior provided for the purpose. The crank is furnished with a ratchet, by which an intermittent motion may be given to the drill, if needed, for corner work.

The tool is supported by an adjustable bracket, or "old man," as it is called in shop phraseology, which may be secured to any work in the ordinary way. It is not difficult to perceive, from the description here given of the tool, that it will perform its functions well, and when once introduced it will doubtless be preferred to the ordinary ratchet, because of the rapid and certain movement of the drill.



SELF-FEEDING HAND DRILL.

Manufactured by C. VAN HAAGEN & Co., Philadelphia.

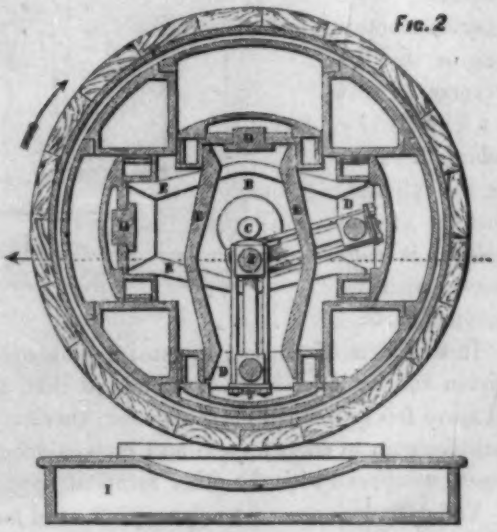


The Kipp Steam Engine.—The engine of which we herewith present external and sectional views, is at present on exhibition at the fair of the American Institute, and has attracted from the scientific press an unusual degree of attention and comment, as one of the most curious and ingenious in design of any yet presented to the public.

The machine bears an external resemblance to the rotary kind, but is in reality simply an ordinary cylinder and piston engine, though of novel construction. The engine possesses two cylinders, coupled at right angles, as will be seen by inspection of the sectional views. These cylinders are divided in the centre, thus forming four single acting cylinders; and the piston heads are connected by double rods, so as to play side by side. Fig. 1 is a perspective view; Fig. 2 is a vertical section at right angles to the main axis of rotation; Fig. 3 is a vertical section cut lengthwise through the axis of rotation.

A is the induction-pipe through which steam passes into the central space, B, exerting pressure equally in all directions. This central space is the steam-chest, which, although its form and position relative to the center of rotation, C, Fig. 2, is constantly changing, serves only as a receiving chamber for the steam which is subsequently to act successively on the outer sides of the pistons, D. These pistons are coupled together in pairs by the connecting pieces, E, so that what at first seems four distinct pistons is in effect only two working in two separate cylinders, the axes of which cross each other at right angles, thus doing away with the dead-center.

Fig. 2



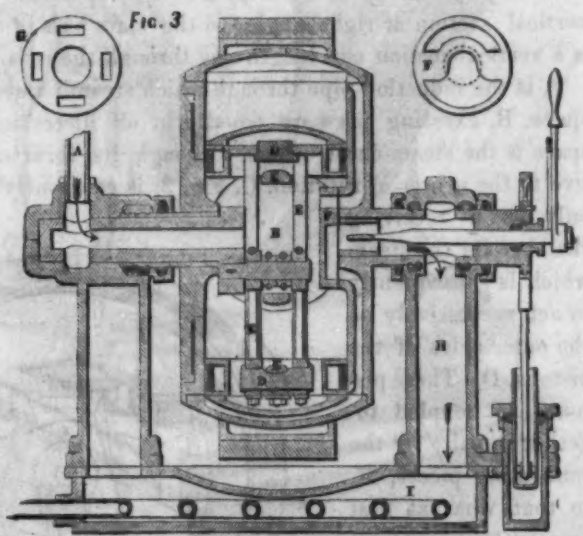
The admission of steam is controlled by a stationary valve, F, a plan of which is shown in detail at the upper part of Fig. 3. The

admission ports move over the surface of this valve. These ports are shown in plan at G, Fig. 3.

H is the exhaust communicating with the feed-water heater, I, formed in the base or pedestal of the engine. The force is applied at the center of the fixed crank, J, and in the direction indicated by the arrow at the end of the horizontal dotted line in Fig. 2, and the rotation of the exterior lagged cylinder is therefore, of course, in the direction of the curved arrow in Fig. 2.

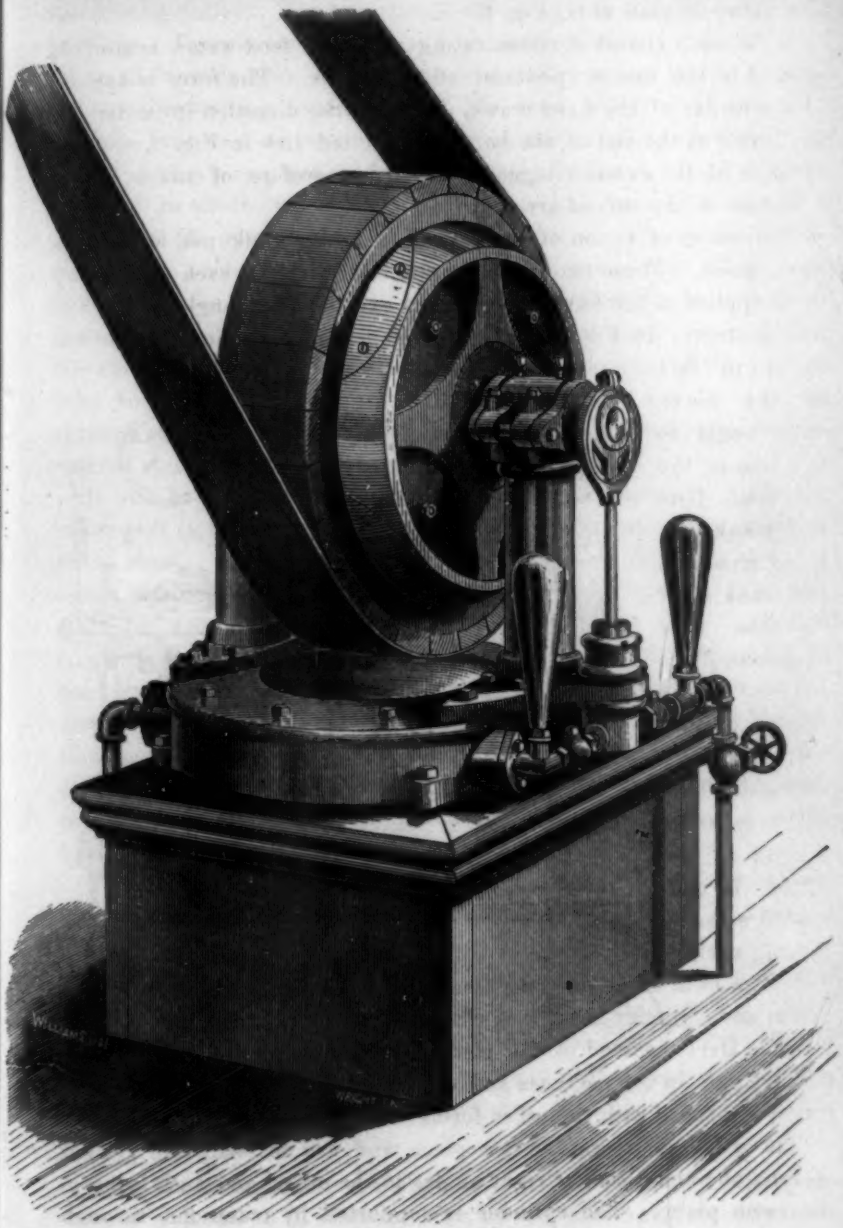
The center of action of the pistons is J, the crank pin, which is a fixed point. These two centers being eccentric to each other, any force applied in the line of one will be exerted at an angle to the line of the other. In Fig. 2 the right hand side piston is in this position. It is in fact at the maximum angle to the line of the crank. But the crank *pin* being fixed and the crank *shaft* movable, the operation of this engine is the reverse of that ordinarily adopted. That is, the cylinder, instead of the piston, is connected with the moving parts.

Fig. 3



In this form of engine, the steam pressure being the same on the piston and cylinder-head, it is claimed that, by allowing the cylinder to move freely instead of the piston, there is no loss of power, but a positive gain in compactness and convenience of form for many purposes, compared with the other forms of reciprocating piston engines.

The cylinders are cast in one piece, and are not liable to get out of line, one being cast at right angles to the other, and both lying in the same plane. The cylinder is supported by trunnions, through one of which passes the crank-shaft; the other carries away the ex-



THE KIPP ENGINE.

haust-steam and drives the feed-water pump. The lagging serves as the driving-pulley. The two pistons are fitted with the ordinary ring-packing. The connecting-rods are so made that any motion taken up on the wrist-pin is, at the same time, taken up on the crank-pin, the strap extending around both. The valve, which is of the slide kind, is bent so as to cover the ports on the circular valve-face. It is cast in one piece, and is held stationary by the crank-pin, unless reversed, in which case it is moved over one-half turn by means of a lever from the outside, thus changing the motion. One of the pillars or supports serves to carry the exhaust steam to the base, which base is used as a feed-water heater, all forming together the framework of the engine. The crank-shaft is keyed fast at its outer end, and, with the valve, is stationary when the engine is in motion. Both pistons take hold of the same crank, the connections of the one passing through the other. There is no dead-centre, and the engine can be started at any point by turning on the steam.

It will be observed that one part of the piston serves to guide the other part in the same line, the space between becoming the steam or valve chest. Both sides of the piston being of the same size, the steam acts constantly upon the full area, there being nothing to subtract for area of cross-section of piston-rod. The valve is so constructed as to cut off at any desired point, so that the steam can be used expansively. No fly-wheel is required unless the work be unsteady. The engine is complete in itself, requires no special foundation, can be very readily and quickly set up, and occupies but little space, and the inventor claims that in design and construction it comprises all the elements of durability and economy to be found in the best reciprocating engines.

The machine on exhibition in New York is a six-horse power engine, 20 inches square, thirty inches high, with 7 × 7 cylinders, and weighs about 5 cwt.

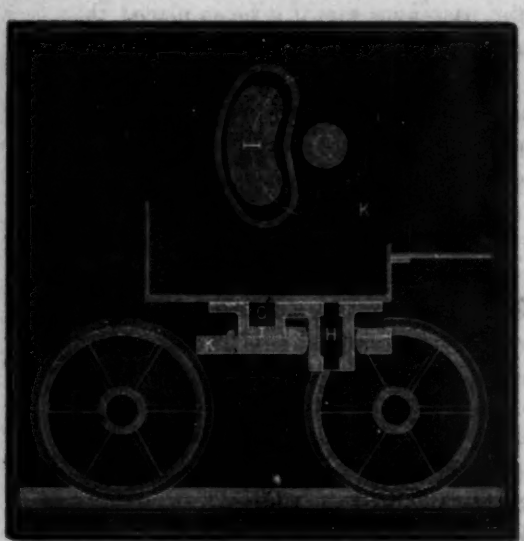
The compact form and simplicity of construction possessed by this engine will doubtless win for it an extended introduction for a great variety of work. It seems to be especially well adapted for the lighter forms of duty, and the proprietors strongly urge its serviceability for operating sewing machines, elevators, &c., for which, it is claimed, it possesses peculiar advantages.

The Westinghouse Air-Brake.—An official trial of this invention, so well known in America, was, we are informed,* recently made

* Engineer, xxxiv, 112.

in England, upon the line of the South Eastern Railroad Company, in the presence of the officials of the company and a few invited experts. The distances passed over, and the time required in stopping in connection with the action of the brake, were carefully noted. When the trial commenced the speed was 40 miles per hour. In eighteen seconds after the application of the brake the train was brought to a stand still, in a distance of 145 yards, with a falling gradient of 1 in 142. On the second trial, with a speed of 30 miles per hour, the train was stopped in 15 seconds after the application of the brake, in a distance of 100 yards, with a falling gradient of 1 in 120. Several other experiments were made, and the results are stated to have been equally successful; and the opinion is expressed that the results of the company's experiments will have the effect of bringing the brake into as extensive an employment in England as it has attained with us.

A New Car Truck.—The following report upon the examination of this device, invented by Mr. William Petit, will require no comment. The accompanying cut shows the truck in vertical and side section.



"The Committee on Science and the Arts constituted by the Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts, to whom was referred for examination William Petit's Truck, report,

"That they have examined the truck as it has been in use under four passenger express engines running upon the P. W. & B. R. R., on which a member of the Committee has travelled several hundred miles.

"The peculiarity of this truck consists in having the centre pin,

upon which it turns, placed behind the centre of the truck. As now constructed, the centre pin is 24 inches nearer the line of the rear axle than that of the front; a sliding bolster, carrying the weight of the boiler, being placed upon the centre of the truck, covering the place usually occupied by the pin. The result of this arrangement is that the amount of force requisite to turn the truck on a curve is less in proportion as the leverage of the leading wheels is increased beyond that which they have when the pin is in the centre of the truck. In passing curves, the centre of the boiler is carried nearer to the outer rail, so that the shock of entering or leaving the curve is diminished. Comparisons made during the past year between engines provided with this truck and those without it, show that with it the side shock incident to entering or leaving a curve is so much diminished that with curves of long radius the shock is scarcely perceptible.

"When used as a following instead of a leading truck, as in running an engine backwards, this truck is drawn into the curve by a pull upon the centre pin, rather than by pressure upon the flanches of the wheels, so that it can be used for passenger cars if it be so placed that each centre pin is nearest that end of the truck which is towards the centre of the car.

"The softening of the side blow resulting from the use of this truck diminishes the wear and tear of rolling stock and roadway, and at the same time increases the safety of railway travel.

"CHARLES M. CRESSON, M. D.,
EDWARD LONGSTRETH,
B. H. BARTOL."

An Interesting Railway Embankment.—Prof. J. P. Lesley, has recently published an interesting account of a natural dam or embankment, which is made use of by the Midland Railroad. This embankment crosses the bottom of the Walkill valley, which runs in a north and south direction for many miles.

The valley contains outcrops of white and blue limestone, which have a steep dip. The west side of the valley is formed by a range of hills of crystalline limestone, in which the celebrated Franklinite iron and zinc ores, for which New Jersey is so well known, occur. All the outcropping rocks of the valley and hills are rounded and polished, grooved and scratched by ice, as they are in the Alps. Sand, gravel and erratic blocks by their presence indicate, with the scratching and polishing of the rocks, the former presence of a glacier moving to the southward.

The natural embankment referred to is thus clearly shown to have been the terminal moraine left behind by the glacier, in growing smaller as the glacial era drew to its close. The embankment consisted throughout of sand, gravel and boulders. It is stated by Prof. L. to be about a mile long, abutting against the Walkill Mountain on the east, and against Sterling Hill on the west. Its height is about 100 feet, and width at the base 250 feet, resembling very closely an artificial railway embankment, of which the Midland Road has very appropriately taken advantage.

From the description given of it, it is without doubt one of the most interesting and complete evidences of the former activity of glaciers in our latitudes which have been yet observed.

The Hoosac Tunnel.—From the latest reports published upon the progress of work upon the Hoosac Tunnel, it appears that it is being pushed vigorously to completion. A full complement of men are engaged in drilling at the eastern and western ends. At the centre shaft an accident, disabling the pumps and flooding the excavation with water, caused a suspension of the work for several months, but it is reported that the damage has been repaired and work here resumed. But 875 feet of rock remain between the work on the eastern end and that of the centre, and about 3,600 between the western and centre work. The contractors estimate that, if not delayed by unlooked for accidents, the mountain will be pierced before the end of the next year.

The St. Gothard Railway Tunnel.—It is stated, in relation to this enterprise, that the company have broken off all treaty with the Public Works Company of Turin, of which Signor Grattoni is President, on account of the exorbitant demands of the company for constructing the Tunnel; and that the work has passed into the hands of Mr. Favre, who represents a body of French and Swiss capitalists, and who agrees to finish the work within eight years, a large sum being deposited as security for good faith. The details of the contract are not stated, but it is declared that the sum of 5,000 francs will be paid to the contractor for each day that his work is finished before the time specified, and that he will be fined in a similar amount for each day of delay in fulfilling his contract.

Experiments on the Structure of Iron.—Recent experiments made in France throw some positive light upon the often discussed question of the change in structure of wrought iron. The apparatus,

according to a valued contemporary,* consisted in a bent axle, which was firmly fixed up to the elbow in timber, and which was subjected to torsion, or twist, by means of a cog-wheel connected at the end of the horizontal part. At each turn, the angle of torsion was twenty-four degrees, and a shock was produced each time that the bar left one-tenth to be raised by the next. Seven axles were submitted to the trial. In the first, the movement lasted one hour, 10,800 revolutions and 32,400 shocks being produced; the axle, two and six-tenths inches diameter, was taken from the machine and broken by an hydraulic press, but no change in its texture had occurred. In the second, a new axle having been tried four hours, sustained 129,000 torsions, and was afterwards broken by means of an hydraulic press; no alteration was perceptible to the naked eye, but, tried by a microscope, the fibres appeared without adhesion, like a bundle of needles. A third axle was subjected, during twelve hours, to 338,000 torsions, and broken in two; a change in its texture and an increased size in the grain of the iron were observed by the naked eye. In the fourth, also, the axle was broken in many places after 110 hours and 2,553,000 torsions. In the fifth, an axle submitted during 23,328,000 torsions, during 720 hours, was completely changed in its texture. In the sixth, after ten months, during which the axle was submitted to 78,735,000 torsions and shocks, fracture produced by an hydraulic press showed clearly an absolute transformation, the surface of the rupture being scaly like pewter. The seventh axle, submitted to 129,304,900 torsions, presented a surface of rupture like that of the sixth; the crystals were found to be perfectly well defined, the iron having lost every appearance of wrought iron.

A New Safety Lamp for Miners.—At the recent meeting of the British Iron and Steel Institute, held at Glasgow, Dr. A. K. Irvine read a paper upon a new safety lamp for miners, for indicating by sound the presence of explosive mixtures of gas and air, based upon a new form of singing flame, and on a fog-horn on the same principle. Dr. Irvine seems to depend for the principle of his invention upon the observation first made by Mr. Barry, and noticed in a former number of the "Journal," namely, that a mixture of any inflammable gas or vapor with air in explosive or combustible proportions, when caused to pass through and ignite upon the surface of a disc of wire gauze whose meshes are too fine to permit of the downward passage

* U. S. R. R. and Mining Register, Vol. xvii, 20.

of the flame, and is surrounded by a suitable tube or chimney which prevents the entrance of air except through the gauze; under these circumstances the flame is set into vibration, which, being communicated to the ascending gases within the chimney, causes the same to emit a sound, which varies in intensity and pitch with the height and calibre of the tube.

Upon this principle Dr. Irvine states that he has constructed a miner's lamp which, upon its approach to an explosive mixture of fire-damp and air, will emit a musical note of warning to the miner. It is to be regretted that the description of the details of the construction of this instrument are too imperfectly stated to give one a clear idea of its form. The lamps, as it is stated, were presented for inspection at the meeting, and exhibited in operation with experimental explosive mixtures, and all present distinctly heard the singing of the flame.

So great was the interest exhibited in the paper, and so satisfactory the experiments, that the assembly unanimously passed a vote of thanks to the author at their close. We shall doubtless very shortly be favored with a fuller description of this invention, which, if it realizes the encomiums passed upon it at the meeting of the Iron and Steel Institute, is really invaluable, and as great an improvement upon the safety lamp of Davy as was this upon its predecessors.

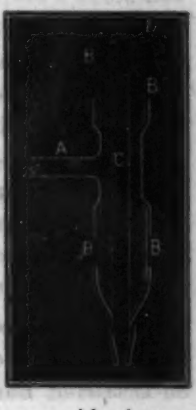
The credit of having first devised a flame of this kind, a sensitive and singing flame within a chimney, is, without question, due to Prof. W. E. Geyer, who published in several of the scientific journals, some months since, a description of such a flame, as a great improvement upon that of Barry, which had then only lately been made public.

To the best of our knowledge, however, the whole merit of the practical application of the observation to safety-lamps, fog-horns, etc., etc., belongs to Dr. Irvine.

Recording the Blows of the Steam Hammer.—We are informed by Mr. Coleman Sellers, that recently having occasion to count the blows of a rapid striking steam hammer, which was thought to be making three hundred blows per minute, three careful observers, counting the blows at the same time, made a variation of from 275 to 325 in the same count. Believing that such observation could not be relied upon, he connected a recording telegraph instrument to the machine, placing two keys in the circuit. One key was closed by each blow of the hammer, a wire from it being attached to a rock shaft in

the valve motions; the other key to be closed by hand. When the hand key was closed, dots were recorded on the paper ribbon, one dot to each blow of the hammer; and by keeping the hand key closed any definite time, a row of dots, equivalent to the number of strikes in that time, were recorded, which dots could be counted afterwards at leisure. Many experiments were tried with this apparatus attached, and, as a rule, it was found that most persons who attempted to count when the speed was near 300 blows per minute, over counted rather than under counted. Very seldom did the count of any observer tally with the count of the instrument.

Water-Bath with Constant Surface.—In addition to the several forms of continuous water-bath already made public, the one here figured, and which is used in the laboratory of Prof. Kolbe, is worthy of mention.



From the side walls of a water-bath leads a copper tube, A, which carries the arrangement shown in section in cut. In the continuation of the tube, A, there are attached, above and below, short glass tubes, B. Within these tubes is placed a narrower glass tube, C, which is firmly attached to B, by means of a caoutchouc ring. This tube, C, can also be readily moved up or down. The height of this tube determines the water level in the bath. The water from the service pipes enters by the cock, D, and fills the bath to the desired level, while the excess flows away through C. The cock, D, can be so arranged as to provide just a trifle more water than is necessary, and when once adjusted the bath is continuous.

The Spheroidal State of Water.—A New Experiment.—Mr. W. F. Barrett stated before the British Association that having occasion to cool a red hot copper ball, it was plunged into a vessel of water in which he had just washed his hands. The ball entered the water without any hissing or perceptible evolution of steam; and, upon being removed, seemed as brightly incandescent as before. Desiring to experiment further upon this phenomenon, other metal balls were tried with the same result. The soapy water was then replaced by fresh water; but, upon plunging an incandescent ball into

this, the hissing was loud and the evolution of steam copious. The author draws from these experiments the inference that the presence of the soap in the water contributed to the formation of the spheroidal state. Further observation showed also that albumen, glycerin and organic matters generally, facilitated its occurrence. He gives the following directions for reproducing the experiment: Pour a little soap solution into a large beaker of water, and then, by means of a hooked wire, lower into the liquid a white hot metal ball several pounds in weight, and best, of copper. The ball smoothly enters the water, and glows white hot at a depth of a foot or more beneath the surface. Notwithstanding the considerable hydrostatic pressure, it is seen to be surrounded by a shell of vapor perhaps half an inch thick.

The vapor shell is bounded by an envelope that resembles burnished silver, and has a most striking appearance. In fact, the hot ball blows a soap bubble of steam from the limiting surface of which the light is totally reflected. As the ball cools, the shell becomes thinner and thinner, and finally collapses, when immediately there follows a loud report, volumes of steam are given off, and often the vessel is broken by the violence of the action.

Following out the same idea, the author seeks to establish, though we think incorrectly, a possible relationship between his phenomenon and certain boiler explosions, from the possible entrance into boilers, on unfavorable occasions, of oil or other organic matter.

The Brooks' Paraffin Insulator.—As another indication of the introduction of mechanical details affording greater scientific precision to the art of telegraphy, it is worthy of notice that the Paraffin Insulator, which has long been recognized amongst scientific men as incomparably the most efficient means of securing the insulation of wires under all circumstances, is steadily supplanting the inferior instruments yet in general use. It is good illustration of the tardiness with which most reforms are accomplished, to find that, though difficulties in the working of long lines of wire are constantly occurring, and acknowledged to be due to the imperfect insulation afforded by glass during unfavorable weather, the general introduction of this most efficient remedy for the evil has not yet been effected. That a proper appreciation of the superiority of the Brook's insulator has at length occurred, appears probable, from a recent order issued by the General Manager of the Penna. Railroad, in which he directs that the Paraffin Insulator of standard size (6 inches in length), is to be employed on all new telegraph lines of the Company, and in repairs of the old ones.

The Disintegration of Metallic Tin.*—Dr. Isidor Walz, in a communication to a contemporary, records a remarkable instance of the phenomenon mentioned above. The chemical services of the author were called for, by the U. S. Ordnance Department, to examine several pigs of metal which had been purchased as "Banca tin," and which had lain for some time quietly in the store-house. One of the pigs had crumbled almost entirely to gray granular powder, and what was left could readily be rubbed to powder between the fingers. In the other pig the process of disintegration had already set in, but was confined to the edges. Suspecting fraud, an accurate analysis was made of the material, which proved, however, to contain nothing but metallic tin. It seems, too, that another case of the same kind is upon record. The cause of this remarkable physical condition of the metal remain as yet uninvestigated.

A New Material from Paper.—From a process recently patented by Mr. A. F. Schmidt, of Pittsburgh, it appears that by appropriately treating paper, or paper pulp, or other vegetable fibre, with a solution of the chloride of zinc, a material is obtained possessing in an eminent degree the properties of toughness and even hardness. The quality of the product may be varied; that is, it may be made so as to retain any degree of flexibility or of toughness, by varying the strength of the zinc solution through which it is passed, or the time of its immersion. The material thus prepared may be applied to many of the uses to which metal, leather, hard rubber, &c., are now put.

It is the present design of those interested in the process to employ it largely in manufacturing a substitute for oil-cloth. For this purpose a very flexible though extremely tough material is produced, which readily takes the colors, and is free from the troublesome cracking and splitting off of the paint, which, as all are aware, is a bad quality possessed by the ordinary oil-cloth.

We append below a list of different articles made of the material, which were exhibited at the last meeting of the Franklin Institute: oil-cloth, patent leather (a heavier product, designed for soles), pipes (suitable for gas conduction), whip handles, saw handles, knives, forks, combs, buttons, washers, roofing material, and last, but not the least interesting, car-wheels, made by bringing upon a metallic framework, a number of concentric discs, of the hardest and toughest kinds of the material, and firmly attaching the same by through bolts.

* American Artizan, iii, 1, 129.

From the fact that it is possible to graduate the character of this material so as to produce a product having any required degree of hardness, toughness or flexibility, it is fair to presume that it may soon find its way into a variety of uses.

It need only be remarked in conclusion that the paper may either be treated after manufacture or in the pulp. The paper is left unsized, and passes through the zinc bath at a tolerably rapid rate, remaining in it but a few seconds, and passes from thence between rolls, when the excess of the chemical is removed, and subsequently through water.

Glass Plummer Blocks and Axle Bearings.—It is announced that Messrs. De Camus & Haret* have succeeded in effecting the substitution of glass for metal in the manufacture of the above named parts of machinery, and with satisfactory results. It is claimed for them that they save greatly in the first cost of manufacture, and that they are very economical in their consumption of lubricators.

Shaping Soft Rubber with the File.—President Morton informs us that he has found it very convenient to finish up the pieces of thick sheet rubber used in making up his various forms of tanks, for use with the magic-lantern, by filing.

The piece to be operated upon should be firmly clamped, as close as may be, to the surface to be filed, and can then be worked by a dry file either of coarse or fine cut.

The ends of thick tubes can be finished to a true surface likewise by fitting a cylinder of wood tightly to their interior.

A New Process for Obtaining Ozone.—Dr. Loew has procured a patent upon a plan of manufacturing ozone, which depends upon an observation first made by him some time ago, and which then created considerable discussion as to its correctness, in various scientific papers. The observation is, namely, that if cold air is blown through a flame it is converted partly into ozone. The apparatus designed by the inventor to utilize his process, consists of a number of Bunsen burners, placed in a row, and as many horizontal tubes, arranged at a certain distance above the burners, through which cold air is blown against the flames. Opposite to these tubes are placed a number of funnels, to collect the accumulating ozone. This product is stated to be to some extent impurified with acetylen and

* English Mechanic, xv, 638.

nitrous acid. Those who recall the discussion of the subject when the experiment was first announced will remember that it was asserted that by the plan here named no ozone was generated, but simply a quantity of the lower oxidized nitrogen products.

In the same connection, it may be of interest to note that it has lately been shown that alcohol can be rapidly oxidized into acetic acid by treating it with a ozonized air. The same result occurs with ether. The experiment may readily be performed by pouring into a flask containing ozone a small quantity of alcohol, and agitating the contents for a few seconds. If the liquid is then tested, it will be found to give a strong acid reaction, from the presence of the acetic acid formed. The characteristic odor of the alcohol will, likewise, be found to have disappeared.

Microscopical Photography.—L. Erckmann contributes the following information in this field, which may be of interest. If thin sections of plant preparations are laid over night in an aniline red solution they will be thoroughly colored. If these sections are then washed with water the nitrogenous parts of the same will retain the red color, while the non-nitrogenous portions will give it up. In making such preparations, it is well to observe that the aniline solution should not be too concentrated, otherwise the image seen in the microscope will be red throughout, and show no shading. This treatment is of some value in photographing such preparations, inasmuch as the image will show great contrast. As the red rays have but little action upon silver iodide, a positive print will show very dark in the nitrogenous portions and much lighter in the others.

The Effect of High Pressures upon Life.—At a recent meeting of the French Academy M. M. P. Best read an interesting paper containing an account of certain experimental researches on the effects of changes of barometric pressure on the phenomena of life.

Amongst the facts announced, he mentioned the case of an English Company, which in a single year lost ten divers out of twenty-four. Of these unfortunates, three died immediately on coming to the surface from great depths, that is, immediately after their sudden release from a high pressure; and seven died after months of suffering from paralysis.

The author, as the result of a number of experimental trials made upon cats and dogs, draws some conclusions which may be found to be of great practical importance to miners, divers and others who are

obliged to labor continuously under high pressures. Up to five atmospheres, the author recommends two or three minutes should be allowed for the pressure to gradually diminish; above this pressure much more time should be allowed, and at nineteen atmospheres five minutes per atmosphere should be taken for their gradual return to the normal pressure. Under the latter condition, if the pressure is allowed to decrease more rapidly than this, death is certain.

A Lecture Experiment.—At the recent meeting of the British Association, mention was made of an experiment devised by Prof. Maxwell, F. R. S.,* whereby the beautiful effects of the mirage were obtained by means of three liquids of different specific gravities, enenclosed in a cubical vessel with plate glass sides six inches square. The lowest liquid was a saturated solution of alum, the highest pure water, and the intermediate one a film of ¼ inch of Scotch whiskey mixed with enough sugar to increase its gravity to the required point. Triple images can be obtained, with its aid, of all objects viewed through it, the middle image being inverted, and either elevated or depressed, according to the position of the eye.

The American Association Meeting.—The 21st meeting of the American Association for the Advancement of Science, was tolerably well attended, in spite of the extremely inconvenient location chosen for the gathering. The number of papers presented, though not so large as usual, were many of them of importance, and several of them are in course of preparation for publication in the Journal.

The officers elected for the ensuing year are as follows: For President, Prof. Jos. Lovering, Mass.; Vice-President, Prof. A. H. Worthen, Ill.; Perm. Secretary, Prof. F. W. Putnam, Mass.; General Secretary, Prof. C. A. White, Iowa; Treasurer, W. S. Vaux, Pa.

Portland, Maine, was chosen as the place for the next annual meeting.

Errata *in article on Anthracene and Chrysogen, on page* 269.

The cuts 2 and 4 have been transposed by the printer.

On p. 269, seventh line from foot, for Mr. Cheene read Mr. Chever.

In note at foot of p. 270 for lamelleme read lamellene.

On p. 273, eleventh line from foot, for Petrolescene read Petrollucene.

* English Mechanic, xv, 361.

Civil and Mechanical Engineering.

TRANSMISSION OF MOTION.

A Lecture delivered by COLEMAN SELLERS *at the Stevens' Institute of Technology, Hoboken, N. J., February 19th*, 1872.

Revised for publication in the "Journal of the Franklin Institute."

(Concluded from page 243.)

What I have said in description of the modern hanger holds good in the various forms of bearing, suited to various uses, where hangers are not admissable. Thus, when the shaft is to be carried by stone piers, not likely to lose their horizontal adjustment, or in case of vertical shaft, pillow blocks are used in place of hangers. I have an example here (Fig. 10.) The box is furnished with spherical surfaces to fit in sockets in the casting or frame; it is self-adjusting as to line, but cannot be raised or lowered as in the case of the hanger. It takes the place of what is known as the clamp-box, and of any rigid bearing not adjustable. It was a clamp-box that I found among the many ingenious illustrations of mechanical devices in the cabinet in the room of your Professor of

Fig. 10.

Fig. 11.

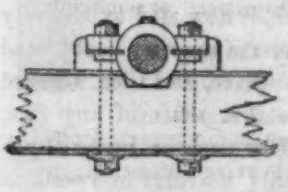
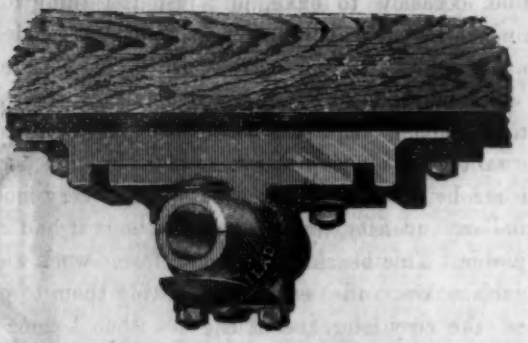


Fig. 12.

Mechanical Engineering. I have it here (Fig. 10). It is very simple in construction. It is made of two pieces only; don't look as if it would be expensive to make, and just the thing for the "anything-is-good-enough-so-that-it is-cheap-people." But does first cost constitute cheapness? let us see. Once upon a time, I thought a circular saw, operated by foot power, would be a very good thing to have in the house. I had a suitable band fly wheel and treadle; all I wanted was a saw-mandrel and circular saw. These were furnished by a saw maker of renown, at a very moderate cost, say seven dollars and fifty cents. For bearings it had *clamp boxes*, lined with Babbitt's metal. A neat wooden frame-work was soon made to receive the boxes, and the work of fitting them to place begun. This did not take very long, it is true; but when I came to screw up the holding down bolts, the spindle would not revolve, so a little more cutting and carving was needful; and at last, after much patient labor, it seemed all right, and the saw was turned very satisfactorily. In a few days, however, it was fast again, and I found the frame had sprung from warping, and had to be refitted. All this careful work would not have been requisite had the saw been driven from a steam engine; but foot power is of limited capacity, and any serious loss from friction is soon felt. Now had this spindle been provided with ball and socket bearings, all the work needed would have been to bolt them to an approximately true surface, and they would have made their own alignment, and would never have bound or cramped the spindle. Why, those clamp boxes would have been dear at half the money, when the cost of fitting, &c., is taken into consideration. I have seen a saw mandrel, with an 18″ saw, running in cast-iron ball and socket bearings, working well after 16 years' hard usage, and during that time never having been adjusted, and that spindle is to-day as good as when it was made.

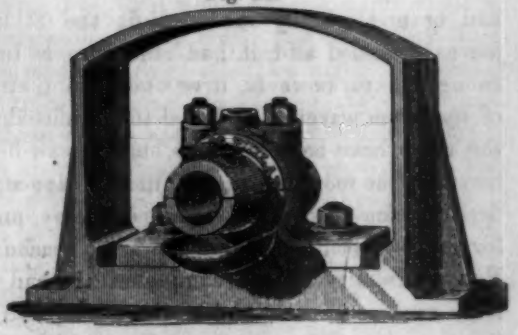
Pillow blocks are sometimes used in connection with cast-iron wall plates upon which they rest, and are secured by bolts. I have an example of such a construction (Fig. 12). This same combination inverted with an oil dish on the cap of the pillow block, is now used extensively to carry the head shaft of long lines, as it admits of the very heavy head shaft, with large pulleys, being hoisted into place, and then secured by the cap and bolts. Head shafts, or the first shaft of any line, usually rest in two bearings. Fig. 13 shows such an inverted pillow block. Sometimes it is requisite to build bearings in a wall, in which case what is called an arched wall box (Fig. 14) is used in con-

Fig. 13.



nection with the pillow block. Very often it is advisable to support the line shaft from the face of a wall, in which case pillow blocks, secured to knees, are very convenient (Fig. 15).

Fig. 14.

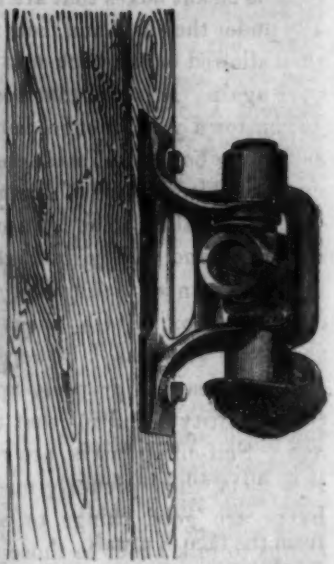


Mr. Bancroft thought all boxes should be made five diameters of the shaft long, *i. e*, a box for a 2-inch shaft should be ten inches long; but it has since been demonstrated that four diameters is sufficient, and that has been the practice for many years. I have here also an example of a hanger to be fitted to a post; it is called in that form a post hanger (Fig. 16). It is in all essential particulars like the ordinary hanger, so far as its adjustment and swivelling principles are concerned.

Fig. 15.

Before leaving the subject of bearings, I would mention that there are examples of cast-iron boxes in use in woolen factories where high speed shafts are running, which show no appreciable wear after 22 years' use. In 1867, I read a paper on journal bear-

Fig. 16.



ings before the Franklin Institute, in Philadelphia, and while preparing that paper I took occasion to examine a bearing in which had been running, for 16 years, a 4¼-inch shaft, with a pulley 72 inches diameter and 20″ inch face, close to the bearing, taking all the power from an engine of 16-inch cylinder, 8-foot stroke, making 50 strokes per minute—say transmitting forty-two horse-power. This bearing showed a bright surface over the extent of one-third of the circumference of the shaft on the bottom half box. The box had been originally made to fit the journal loosely, and it had not worn enough to make it fit over one-third of the circumference of the shaft. In the use of cast-iron bearings, lubrication must be attended to, else the bearing will soon be cut and rendered useless; but lubrication is so easy, and so little oil is needed for the purpose, that there can be no reasonable excuse for neglect. You will observe in the sample of the hanger now before you, two large cavities in each end of the top box; these cavities are called tallow cups. They should be filled with tallow and oil, mixed so as to be of such a consistency as not to be fluid in warm weather. Should the journal heat from any cause this same solid lubricant will melt, and, running into the bearing, will protect it for the time being. The box should be oiled in the centre, and oil holes are provided for that purpose in the recess around the spherical portion of the top box. There is also a hole in the very centre of the ball on top, and the top plungers, which rest on the ball, being hollow, a self-feeding oil cup can be placed on top, and thus deliver oil regularly to the bearing. As to the quantity of the oil needed, I would remark that with shafts running in self-adjusting hangers, with bearings four diameters long, at a speed of 120 revolutions per minute, require, on an average, 2·2 fluid-ounces of oil per bearing for six months' oiling, and self-feeding oilers, placed on top, should not deliver any more than this quantity.

From time to time a great deal is said about self-oiling boxes; by this

term is meant boxes that are made to contain oil in some reservoir usually under the shaft and from which reservoir oil is fed to the shaft, and then allowed to run back into the reservoir and thus be used over and over again. It is said that bearings in self-oiling boxes have been made to run for a year or more without attention, but I have never known a self-oiling box to be made to work well with so little oil as $4\frac{1}{10}$ fluidounces in it. Some of them hold a pint each, and only the other day I was called upon by a manufacturer who required some shafts, couplings and pulley, but who did not want hangers, as he would make his own *self-oiling hangers*. I asked him how much oil he put into each box. "Oh, about one pint," he said; "I do not think them safe with less." One pint is 16 fluidounces, quite enough oil to last four years, if properly applied, and yet it would never do to trust that quantity of oil for that time, as it would become deteriorated by age. Self-oiling boxes are rather more costly and take more oil to run them, than properly made bearings oiled by hand. Self-oiling boxes are good things to sell—better than to use; they are good things to talk about to those who do not know what true economy in oiling is. Glass oil-cups above the bearing, feeding oil at such a rate as to consume $2\frac{1}{4}$ fluidounces in six months, to say hangers for $2\frac{1}{4}$ shafts, are the best, and oil fed at this rate will not run out of the box ends, but will just supply the waste from consumption.

All shafts, long or short, must be provided with some means of preventing end motion. Line shafts should have one pair of collars fitted to one of the bearings only. The collars placed usually on the first or head shaft should control the position of the entire line; more collars are apt to cause needless friction. When shafts are collared, the collars should be fast to the shaft; loose collars held in place by set screws are sometimes used, but are more expensive and cumbersome than the fixed or fast collars. Some engineers prefer necking in the head shaft to some smaller size in the journals. Suppose the first or head shaft require to be made of iron $6\frac{1}{4}''$ diameter, to sustain the driving belt. This shaft might be necked in, and be carried by bearings, say $5\frac{1}{4}''$ diameter, and the ends still further reduced to the size of the shaft to be coupled to it. This practice of necking in the bearings of the head shaft is common in modern cotton-mill practice, has the advantage of diminishing the velocity of the surface motion and of the shaft in the box; for by diminishing the diameter we diminish the speed of the rubbing parts, and the tendency to heat is much ncreased with increase of velocity.

To determine the size of shafts for the transmission of a given power, a safe formula is $D = \sqrt[3]{\frac{P}{R}} \times 125$, D being diameter of shaft, P the horse-power, and R the number of revolutions per minute. This gives a shaft strong enough to resist flexure, if the bearings are not too far apart. The distance apart that the bearings should be placed is an important consideration. Modern millwrights differ slightly in opinion in this respect; some construct their mills with beams 9′ 6″ apart, and put one hanger under each of the beams; others say 8 ft. apart gives a better result. I am clearly of opinion that with 8 feet distance, and shafting lighter in proportion, the best result is obtained. The tendency now is to increase rather than diminish the speed of line shafts, and good practice is to run shafts for machine-shop purpose at 120 revolutions, for wood-working machinery at 250 revolutions, and for cotton and woolen mills at from 300 to 400 revolutions per minute. Hollow or pipe shafting has been made to run at 600 revolutions per minute, very satisfactorily. This kind of shafting is, however, too costly to be generally introduced.

Mr. James B. Francis, of Lowell, writes me that since the decrease of the water-power in that town, or rather the rapid increase of the factories, they have been obliged to economize their power, and they are doing so by using smaller shafts at higher velocities, and have even made extended lines only 1¼ inch in diameter. They so arrange the mill as to secure a hanger close to each transmitting pulley. The torsion in long lines limits the smallness of the shaft used, and in all probability the best result will be found to be obtained in the use of not less than 1¾″ diameter for the smallest line shafts in cotton mills.

There are now running in some factories lines of shafting 1000 feet long each. The power is generally applied to the shaft in the centre of the mill, and the line extended each way from this. The head shaft being, say 5″ diameter, the shafts extending each way are made smaller, and small in proportion to the rate of distribution, so that from 5″ they often taper down to 1¼. In coupling shafts of different sizes it is customary to reduce the end of the larger one to the size of the smaller shaft, and then to use a coupling suited to the smaller size. Fig. 12 shows an example of this method of reducing the larger shaft to the size of the smaller one. The rapidity with which the reduction of the size of the sections is made must depend, in all cases, on the distribution of the power. For instance, if a

line of any length whatever receives its power at one end, and transmits the same amount of power at its other end, such shaft must be of uniform diameter; but if it distributes its power at regular intervals along its length, the shaft may be made in sections of a size proportioned to the power given off.

Fig. 12.

It would be impossible in one lecture to detail all the contingencies that influence this reduction, as questions of expediency will often have a decided influence. While speaking of the relative velocity of shafts, I would like to call your attention to one consideration touching on the economy of fast running shafts. To run a shaft of a given size and weight, say 200 revolutions per minute, must take more power than to cause the same shaft to revolve 100 revolutions, but with increased velocity the diameter of the shaft may be diminished, and with it the diameter of the driving pulleys may also be lessened, and hence the weight on the bearings will be reduced and the velocity of the surface of journals not much increased. With the formula I have already given you for computing the proper size of shaft for the transmission of a given power, at a given velocity, you can readily work out comparative examples, and thus demonstrate the advantage of high speeds over low ones.

When very long lines of shafting are constructed of small or comparatively small diameter, such lines are liable to some irregularities in speed, owing to the torsion or twisting of the shaft as power is taken from it in more or less irregular manner. Shafts driving looms may at one time be under the strain of driving all the looms belted from them, but as some looms are stopped the strain on the shaft becomes relaxed, and the torsional strain drives some part of the line ahead, and again retards it when the looms are started up. This irregularity is in some cases a matter of serious consideration, as in the instance of driving weaving machinery. The looms are provided with delicate stop motion, whereby the breaking of a thread knocks off the belt shaft and stops the loom. An irregular driving motion is apt to cause the looms to knock off, as it is called, and hence the stopping of one or more may cause others near to them to stop also. This may in a measure be arrested by providing fly-wheels at intervals on the line shaft, so heavy in their rim as to act as a constant retardant and storer of power, which power is given back upon any reaction on

the shaft, and thus the strain is equalized. I mention this, as at the present time it is occupying the thoughts of prominent millwrights, and the relative advantage and disadvantage of light and heavy shafts is being discussed, and is influencing the practice of modern mill construction.

I have mentioned the method of uniting bars of round iron so as to make long lines of shafting, in considering the theory of the coupling. I have given you an insight into the principles involved in a successful bearing for the shafts to revolve in, and I have dwelt a little on the shafts as regards size and velocity. I will now call your attention to the pulleys, or band-wheels. See Fig. 13. The best belts or bands used on these wheels are of leather, kept in good condition by the judicious use of oil. Belts of leather are made of single thickness of leather for some purposes, and of two or more thicknesses for the endurance of harder strains. In general, main driving belts are made double thickness, and belts for transmission of power to machines with some exceptions are made single thickness. The terms double and single belts have come to be applied to leather bands in the trade, while India-rubber belts, now quite extensively used, and often to advantage, have their grades indicated by one-ply, two-ply, three-ply, &c., as indicating their thickness. It is of the utmost importance, for considerations of economy in running, as well as first cost, that pulleys should be made as light as is consistent with strength. Pulleys that are to sustain the weight of double belts must be made heavier and stronger than those that are to sustain the weight of single belts; and the use to which the pulley is to be applied must influence its proportions. In the early practice of making cast-iron pulleys it was believed necessary that the arms should be made something like the letter *S* on the plane of the pulley. The idea was that they would be less likely to break from shrinking strains in the casting. It is quite evident, however, that a

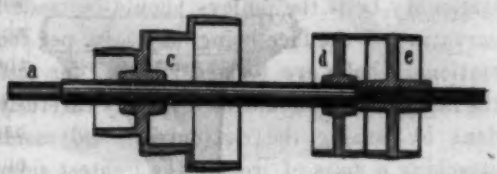
Fig. 13.

straight arm, such as one in the samples shown you (see Fig. 13), representing a straight line from the centre to the circumference, will take the least metal; and I can state as a fact, after very long experience, that pulleys made with straight arms are the strongest, with equal proportions, provided proper precaution be taken in selecting the iron to be used in making and regulating the conditions of cooling. The straight armed pulley can be made with the least possible metal and the greatest possible strength for the metal. Its form is the best able to transmit the peculiar strains brought to bear upon it, and at the same time it is the most pleasing form to the eye. In machinery, as in nature, fitness to intended purposes has much to do with our ideas of beauty. The arms should be oval, so as to present the least resistance to the air in running, and they should be as light as is possible to make them, consistent with strength. This is of the utmost importance, as the weight of the pulleys on the line shafting often is very great, and this metal must revolve with the shafts, and its revolution costs in proportion to its weight. This cost of rotating the mass of metal is a constant cost irrespective of the work done, hence the need of carefully considering the weight and its reduction to the minimum. Pulleys should be turned truly round, and they should be cylindrical only in the case of belts having to be shifted sideways on their face; for stationary belts the pulleys should be made higher in the centre, the curvature of the face being, say $\frac{1}{8}$ in. per foot. In trade, pulleys for stationary belts are termed "high," for shifting belts "straight," on the face. They should be also very carefully balanced. This may be done by turning the rim outside and inside, or it may be done by attaching a mass of iron to the lightest side of the pulley. The former practice holds with large driving pulleys, the latter with the smaller pulleys on the line. Large driving pulleys, when over 8 feet diameter, should always be carefully fitted to the shaft, and be held from turning by a key fitting sideways, never bearing top and bottom. Very large pulleys, say for belts 12 inches wide and over, should be forced into the proper place in the shaft by forcing press, in the same manner as I stated car-wheels are fitted to their axles. The various transmitting pulleys on the line may be so bored as to slide on to their respective shafts and be held by set screws. Pulleys are now made in most large machine-shops of so many sizes that they present the readiest means of regulating the speed of machinery. Some establishments are filled with patterns varying by $\frac{1}{4}$" in diameter for smaller sizes, say under 12", then by $\frac{1}{2}$ in. up to 18" or 20", and after that

by one inch up to 3 feet, and by two inches up to 6 feet in diameter. This variety answers all the purposes of trade. Pulleys made smooth on their face transmit more power than when rough, and are less destructive to the belts used upon them. The power that can be transmitted by a leather belt running on a smooth cast-iron pulley is dependent upon the strain of the belt upon the extent of surface of pulley encompassed by the belt, and the direction that the belt is lead to and from the pulleys; but a very safe approximate rule is to assume that every 1000 feet of motion per minute of each inch in width will transmit one horse-power with single belts. This can be doubled by the use of double belts, but with more severe strain upon the journals. The subject of relative size and width of pulleys, and the various conditions of belt direction, would in itself be enough to fill an hour's lecture, so I cannot enlarge upon it to the extent I would like.

Pulleys are sometimes made loose on the shaft, and are used mainly on what are called counter shafts, for the purpose of starting and stopping machines. Counter shafts are usually short shafts placed over or under the machines to be driven, and, receiving the power from a main line, transmit it to the machine. Thus, I have here an example of a counter shaft for driving a lathe (see Fig. 14). You will observe that this shaft is necked down at its ends, (a and b), to a smaller size; these smaller ends are the journals. It has upon it a cone pulley (c) corresponding with the cone pulley on the lathe head to be driven, the various sizes giving different belt speeds, and it has also a pair of fast and loose pulleys, d, e. Now this may be taken as an example of a counter shaft; but all counter shafts are not made in this manner. The term counter shaft is applied to all shafts driven from the main line when placed at or near the machines to be driven, and sometimes in cotton and woolen factories some really long lines, driven from the main line in the same room, are called counters or counter lines. Such lines, differing in no respect from main lines except in name, need not be especially considered. Counter shafts such as I here show you, Fig. 14, are peculiar in themselves, and must be considered by themselves. In this example there are fast and loose pulleys (d, e). When the belt is on to the fast pulley,

Fig. 14.



d, it will, in causing it to revolve, rotate the shaft also, and thus drive the machine connected with it; but when shifted on the loose pulley (e) that pulley can turn without turning the shaft. Now, you will observe that the shaft in the loose pulley is of the same size as the journal part, and the hub of the loose pulley is longer than its face is wide; this is an important feature, as it insures stability and durability. It makes the pulley run steady, and its extended bearing makes it wear well. It is advisable to so arrange counter shafts of this character as to admit of the loose pulley being near the hanger, so as to admit of the shaft being turned down to the journal size where the loose pulley is. Thus, for a double purpose, the box of the hanger holds the pulley in place between it and the shoulder of the shaft, and the lubrication of the bearing helps to oil the loose pulley, as much of the oil will find its way along the shaft. The hangers for that counter need not be made with a vertical adjustment. They should be provided with the swivelling principle in the box, and as the boxes can be slid on from the end, they may, with advantage, be made solid, not in halves, as are the boxes of line hangers. I have here two examples of hangers to counter shafts, called counter hangers. One of these (Fig 15), is for use on a counter shaft where there are fast and loose pulleys; the arm is to carry a belt shifting rod, which slides in the adjustable guide, and by suitable belt forks is used to push the belt from one pulley to the other. As many counters are made without fast and loose pulleys, there are hangers made without the shifter arm, and this form of hanger is extensively used in factories for the counters of machines having the fast and loose pulley on the machine itself, as is the case with the looms.

Fig. 15.

I have already mentioned that there is a distinctive difference between the shafting system of this and other countries; let me explain this more fully, taking for example the practice that holds in England at the present day. Theoretically, motion can be transmitted

more economically by means of gear wheels than by means of belt. Gear wheels transmit motion without loss by slipping, as might be the case with belts. Gear wheels are used in England to transmit the power of the engine to what is usually called the jack shaft from this shaft, by means of bevel wheels and upright shafts, the power is conveyed to the various stories and thence by bevel wheels to the line shafts. This system insures the transmission without slip to the lines, but it is costly and very cumbersome, inasmuch as very high speeds are not possible with gearing. With a very rapid motion the teeth are broken by the back-lash. Sometimes wooden teeth or cogs are inserted in the driving wheels, and the driven wheels are made of iron with the teeth carefully planed to proper shape. Wood and iron teethed wheels can run rather faster than iron on iron, but still not up to the speed now common in this country. Let us suppose, for instance, that it is found expedient to use no higher velocity to the geared shafts than 100 revolutions per minute, and the machine driven necessitates the use of pulleys 8 feet in diameter to drive them. The first cost of the line would certainly be less if the line could be run at 200 revolutions, and pulleys only 18 inches in diameter used to drive the machines. Well, the practice here is to obtain a speed of say 400 revolutions for lines in spinning rooms, and to use pulleys not more than 9 inches in diameter. These high speeds are not attainable with gearing, so belts from the engine to the line have come to take the place of gearing in all well constructed American mills, and this with a manifest gain in diminished first cost, in economical use and in steadiness and smoothness of motion.

Not very long ago, an enterprising firm imported from England some peculiar spinning machines, and some, to us, novel machines for preparing the wool with the intention of making fine yarns. They also brought out a boss spinner to put up the machines and organize the factory. They consulted me in relation to the shafting to drive the new machinery, and I asked for speeds of machines, &c., to enable me to arrange the proper speed of shafts, power, &c. They referred the matter to this spinner, who said he did not know what speed the machines were to run, but that if I would make the shafts 3 inches in diameter and run them at 100 revolutions per minute, the pulleys should be 36 inches in diameter. This was, of course, information enough to guide me, but, instead of making all the shafts 3 inches diameter, I made some only 2¼ inch, and giving a speed of

two hundred and forty. I could use pulleys only 15 inches in diameter. When the plan was shown to the spinner, he condemned it in toto. These machines could not be driven from any less pulleys than 36 inches; that he knew, and no argument could convince him that the same speed was being obtained at a less cost. The mill owner, a good business man, but not much of a mechanic, was in doubt as to what to do, but was convinced when he saw the estimate of the two systems, one at so much less cost than the other, and when he was shown that the pulleys on the machine were only 12 inches in diameter, hence would require no larger pulley on the line, so far as power was concerned. I could relate many other examples of converts to the American system of mill shafting, whose conversion was brought about through their pockets, but who are now enthusiastic in praise of the entire principle of light shaft, small pulleys and transmission by means of belts in place of gearing.

It is in America only that the production of all that pertains to mill-gearing and shafting has been reduced to a systematic manufacture. To make a machine is one thing; to manufacture machines is quite another thing. Thus one sewing machine may be made by itself at a cost more or less in proportion to the labor expended upon it. But the same machine, by means of organized labor, can be produced in quantities for a tenth of the cost of one machine. Hence systematized manufacture is needed to insure cheap productions. The hanger which Mr. Bancroft showed to the New England machinists would indeed have been an expensive luxury if simply made one at a time, with no special tools fitted to its production; but with most special tools, thorough organization of the labor employed, and the production of immense numbers of them, with all parts made to gauges, and interchangeable, the cost is less now than what the commonest, rigid bearing hangers were made for formerly, and their adoption is now universal. Apart from systemized labor, an important item in first cost is weight of material. Not very many years ago all shafting, and all pulleys, and everything relating to the machine for transmitting motion, was made and sold by the pound. Purchasers were attracted to the makers who charged the least per pound, and no very great care was taken to see that too many pounds did not go into the various parts of the machine. Shafts of a given size could not be made to weigh more or less by different makers; but much needless weight might be put into hangers, into couplings, and into pulleys, so that the price per pound really came to have no meaning so far as total

cost was concerned. Some dozen years or so ago, the house of William Sellers & Co., feeling that this system of selling hangers, pulleys, couplings, &c., by the pound, was not the proper way to dispose of such things, determined on a radical change. They instituted an extensive series of experiments to demonstrate just how strong and consequently how heavy each article comprised under this head should be. They found that pulleys might be reduced in weight, and, by the employment of suitable machinery, be more perfectly made. So of hangers, and all that pertains to shafting, except the shafts. They then published a price list, offering to sell each item at some certain fixed price, dependent upon its own cost. This price list enabled the purchaser to know before-hand just how much money would be required to obtain what he wanted, and for strength and durability he took the guarantee of the makers. There was great opposition to this system from those who were still anxious to sell by the pound; but in time the manifest advantages of the plan caused its adoption by other makers.

Various establishments have been fitted up at great cost for the production of "shafting," and the same attention is now paid to its construction as is given to any other branch of the machine business.

All conceivable wants of the trade are met by specially contrived devices, which can be made in quantities and kept in stock ready for sale. Hangers varying in size and "drop" (i. e. in distance from centre of shaft to the foot), are made from carefully designed patterns. Pulleys fitted for double or single belts, for wide or narrow belts, and made high or straight on the face, are all from patterns nicely adapted to the work each has to do. Last, but not least, all these things are made to standard gauges, so as to have their parts interchangeable. A nomenclature, too, has come into use, and all the technical terms used are in a degree uniform through the trade. In regard to the sizes mentioned, in speaking of shafts, they are called always from the size of the bar iron from which they are made, and the term "shafting size," has come to have a significant meaning. All turned shafts are made from merchantable sizes of round bar iron, and in turning, one-sixteenth is taken off in diameter, so that what is called a two inch shaft is really only one fifteen-sixteenth in diameter, and so of other sizes; they are all one-sixteenth less than their name implies; and the couplings, hangers, &c., are made to conform to these sizes.

The adoption of high speed for shafts has, as I have said, rendered

it almost impossible to employ gearing for the purpose of transmission. Belts have become the recognized means of transmission, and mills formerly driven by gearing are now being altered so as to use belts only. When two shafts are placed parallel, the transmission by belts is a very simple matter; but sometimes shafts are required to be driven at right angles to the axis of the source of motion. This can be done by belts, provided the belts be carried over guide pulleys, so set in relation to the driving and receiving pulleys as will enable the band to lead properly from one to the other. Various devices have been arranged to effect this with readiness, and it is not an unusual thing to carry belts as wide as twenty inches over such guide-pulley, and in all imaginable positions. But this subject is one that would require more than the time allotted to one lecture to fully explain. I must therefore pass it by with this brief allusion to it, trusting that I may have an opportunity at some future time to explain it more fully to you.

The subject of the transmission of motion for the motor to the machine, is, as I have shown, a very important one, and I cannot omit mentioning that I had an opportunity recently to note the comparative tests of power employed in driving two large manufacturing establishments. The amount of shafting reduced to the same basis in each, showed in one case a consumption of ten-horse power to run the empty shafting, and in the other thirty-horse power only. The first was of the improved, self-adjusting kind. The last was an example of shafts in rigid bearings. This will show you clearly how needful it is to study economy in transmission of power; and I trust what I have said to you this evening may at least furnish food for thought, and lead you to inquire into the subject further.

Actinic Action in the Dark.—From an observation of Lieut. Abney, it appears that carbon prints need only be exposed to the light for one-fourth of the usual period; for, if after this brief exposure they are placed away in the dark, they will be found on development to have been fully exposed. It would appear from this that the chemical or physical change in the film is begun in the light, and, when once started, is continued and completed in the dark.

THE USE OF COMPRESSED AIR IN TUBULAR FOUNDATIONS, AND ITS EMPLOYMENT AT THE SOUTH ST. BRIDGE, PHILA.

By D. M. Stauffer, C. E.

The employment of compressed air in founding submarine structures is of comparatively recent date, very recent, in fact, among American engineers; but the magnitude and importance of the two great works carried forward on this principle, at St. Louis and at the East River, have attracted general attention in its direction. By the use of this new agent the bridging of the Mississippi is almost an accomplished fact, despite its deep beds of quicksand, and scouring tendencies, so destructive to the work of the engineer.

The expense attending the process is necessarily very great, but the advantages to trade and rapid transit in spanning streams hitherto considered impassable by other means than boats much more than compensate for the outlay of funds.

With the exception of the official reports of chief engineers, and such hasty and imperfect descriptions as a newspaper reporter might give the public, little has been written on this subject in the United States. The methods employed in prosecuting the work are unknown to the generality of readers; and even the engineer, in search of knowledge of details, must generally translate from a foreign tongue before he can get what he wants.

Under these circumstances it is, perhaps, well to commence our article by giving such a short sketch of the origin and progress of the pneumatic process as the very meagre data at hand will allow.

To Dr. Lawrence Halker Potts, of London, is generally ascribed the credit of first conceiving the idea of making use of air pressure in founding engineering works. His was the "vacuum," or "exhausting," process, in which the normal atmospheric pressure was utilized. His apparatus consisted of the iron cylinder to be sunk, a chamber capable of being exhausted by an air-pump, and a flexible hose connecting the cylinder and the exhaust-chamber, furnished with a stop-cock. The cylinder is tightly closed at top, provided, however, with a trap-door, opening downwards. When the cylinder is placed in position the chamber is first exhausted by the pump, and when the vacuum is as complete as possible, connection is made between this chamber and the cylinder by opening the stop-cock, and the air in the cylinder rushes in to fill the vacuum, leaving, of course, a partial

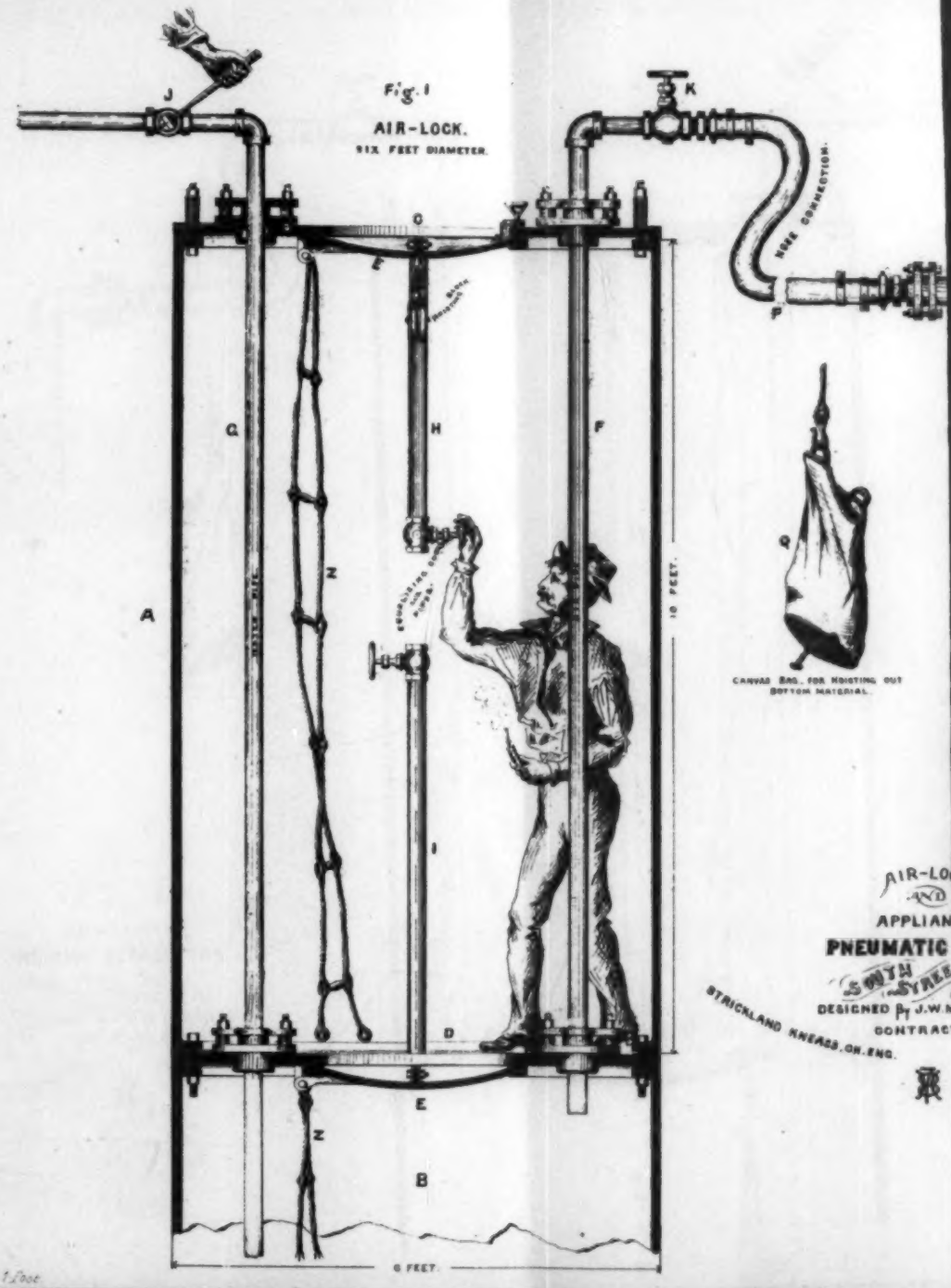
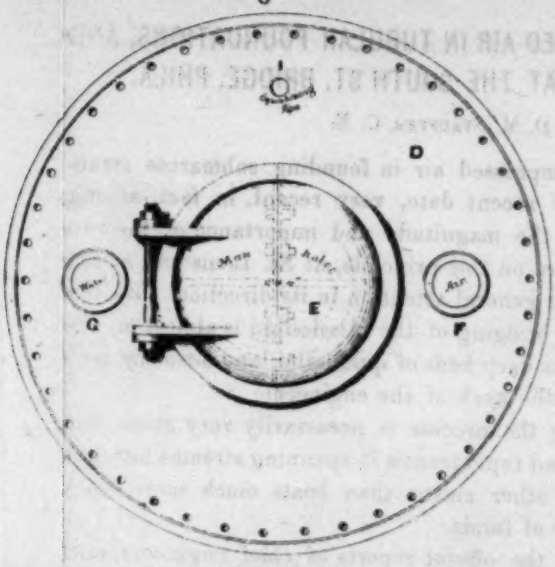


Photo-Zincography by F. A. Wenderoth, 933 Arch Street, Philadelphia.

Fig. 2.



DIAPHRAGM.

OR HOISTING OUT MATERIAL.

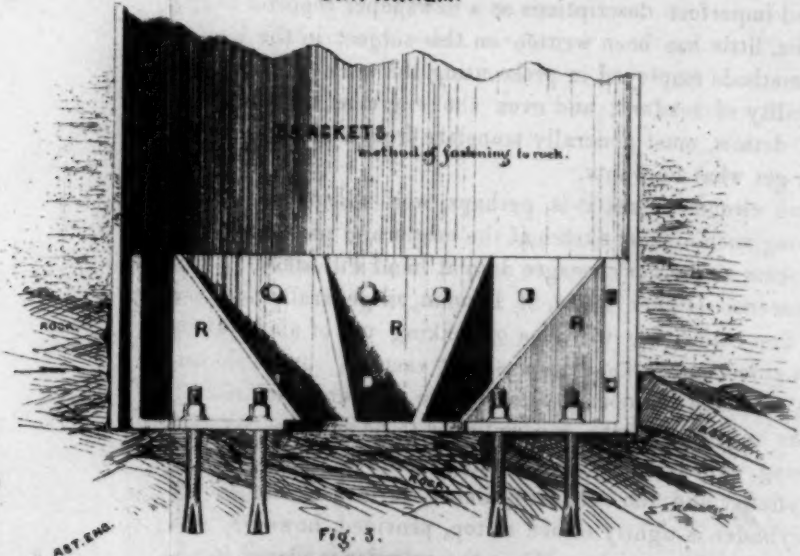


Fig. 3.

AIR-LOCK AND APPLIANCES

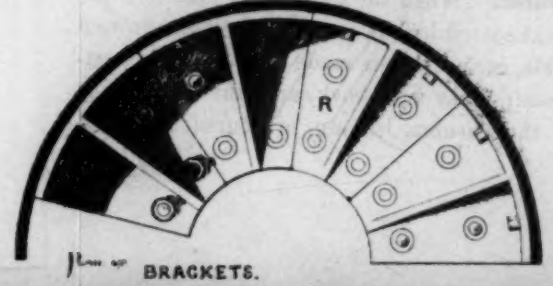
PNEUMATIC COLUMN,

SOUTH STREET BRIDGE,

DESIGNED BY J.W. MURPHY, C.E.

CONTRACTOR.

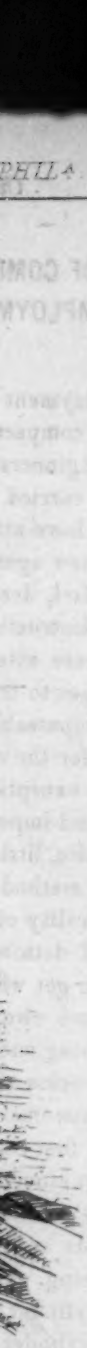
ASS'D. CH. ENG. D.M. STAUFFER, ASS'T. ENG.



Plan of BRACKETS.

Print by A.M. Cozzens, 610 Jayne Street, Philad

PHILA. PLATE I.



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vacuum in the cylinder itself. The atmospheric pressure on the top of the cylinder, then being in excess, acts downwards with a force equivalent to almost one ton per square foot of area; this is augmented by the weight of the iron cylinder; this pressure is also transmitted through the water to the mud and soil beneath, and if they be soft they will be forced up inside the column, that being the point of least resistance. By opening the trap-door and scooping out the mud from the inside, by any means convenient, we prepare for a repetition of the process, until the desired depth is reached. The method of Dr. Potts is only applicable in soft soil and sand, free from logs and boulders. Crude as was this first attempt, it marks an important era in engineering science, and was as fruitful of good results as novel in application.

France claims the honor of improving upon the Potts method, by substituting compressed air for the vacuum, giving us the Plenum process, as it is called, which had the marked advantage of enabling them to exchange for the blind work of the dredging bucket the intelligence of man; for, though life was impossible in the rarified air, man could exist and work in compressed air, as had long been exemplified in the diving-bell.

This new process was first applied about 1850 to the foundation of the bridge of Macon, across the Soane, and very soon after, by Mr. John Hughes, at the Rochester bridge, England. Messrs. Friger, Mougel and Cavè, engineers of the Macon work, on account of local difficulties, instead of the usual stone piers, substituted cast-iron columns, extending to and immediately supporting the superstructure of the bridge. These columns, or hollow cylinders, were 10 feet in diameter, cast in sections and bolted together. The process of sinking them was essentially the same as that which we will fully describe further on; so we will pass on to the next step, merely citing this as the first example of the kind.

The "Caisson method," in which the iron cylinders were enclosed in a pier of solid masonry, starting from the roof of a caisson or rectangular box of wood or wrought-iron, and resting immediately on the rock-bed, was the next modification of the Plenum process. This latter plan was first adopted at Kehl, on the eastern border of France, in a railroad bridge across the Rhine. Any attempt to found the piers at this place by means of the old-fashioned coffer-dam would have been not only tedious but costly, if, indeed, not impossible, on account of the necessity of completing the foundations to the water-

line, between two floods in the river, the exceedingly rapid current, and the indefinite depth of the bed of mud, sand and gravel.

At first the Friger process, as employed at Macon, was proposed; but this was also deemed impracticable, from the amount of time that would be consumed in extracting through a contracted "air-lock" the great mass of material that must be raised in going the depth required. Another objection was the costly weight of metal that iron cylinders would leave hidden under water. Some other plan must be devised, and to M. Fleur-Saint Denis, the engineer in charge, we owe the idea of a caisson.

This caisson was a rectangular box-like structure, closed at the top, and made of wrought-iron, in dimensions 23 ft. x 19 ft. Through the roof of this box were pierced three circular openings, surmounted by shafts of sheet iron, the centre one 5 feet, and the side tubes each 3 ft. 3 in. in diameter. The two smaller tubes were each capped by an "air-lock," similar in purpose and vital arrangement to such as will be fully described further on. These locks gave access and egress to and from the working chamber, through the medium of the tube connected with them. The central shaft was open at top and bottom, with its lower edge extending a little below the level of the bottom edge of the chamber; through it a chain of dredging buckets worked, scooping out a hole which was also lower than the bottom level of the caisson or chamber, and lifted to the surface of the water any material thrown in that hole. These tubes were lengthened as the caisson settled towards the bottom, so as always to keep their tops above water. When the compressed air is forced into the side tubes and the caisson communicating with them, the water in these parts is driven out, and kept out, to the level of the bottom of the working chamber or caisson; but, as the central shaft extends below that level, its bottom edge is under water, and the whole central shaft is filled with water to the normal level of the river. The air pressure in the working chamber, acting on this water column, a little more than counterbalances it, and prevents it from flowing into the working chamber. This water column forms a means of communication between the inside of the caisson and the open air, and through it all the earth taken out by the workmen from the body of the caisson and under its edges is lifted to the surface by the dredge, the men throwing all such material into the hole under the central shaft.

Several of the caissons just described were placed side by side, but communicating to form the support for one pier. Surmounting the

outer edges of the caissons was a wooden casing, or box, extending to and above the surface of the water, and kept above that level by successive additions of timber as the caisson slowly settled towards its final bed. This casing was kept filled with beton, poured in from time to time, which served both to form the body of the pier, and to counterbalance by its weight any upward force exerted by the compressed air. When the desired depth was reached, the caisson and the shafts were likewise filled with beton, and a firm and, of its kind, economical foundation for the pier secured.

The Kehl process is, in fact, essentially the same as that employed to-day at St. Louis and in the East River bridge, modified by such improvements as more mature experience might suggest, and substituting for the beton solid masonry, started upon the roof of the caisson.

These three methods—the Vacuum, the Plenum with iron cylinders and the Plenum in caissons, constitute about the limits of the application of compressed air to engineering works on land.

Having now introduced, in a general way, the process and its history, we come to the more detailed explanation of the method of sinking "pneumatic cylinders," as performed at the bridge over the Schuylkill at South street, Philadelphia.

The process used is the Plenum with iron cylinders. These cylinders are cast from Government cannon, originally made from cold-blast charcoal pig, securing an unexceptionable material to start with.

Their diameters are 8 ft., 6 ft. and 4 ft., respectively, according to the position they occupy in the structure, and they extend from their footing in the bed-rock at the bottom of the river to the superstructure of the bridge, and immediately support it. The bridge was planned for two fixed spans and a draw, necessitating a pier at each end of the draw and a pivot pier. Each end pier is formed by two of the 8 ft. columns, and the pivot pier by a cluster of nine columns, a 6 ft. column in the centre supporting the pivot of the draw, and a surrounding circle of eight columns, 4 ft. in diameter, carrying the track on which the draw revolves. This circle is 36 ft. in diameter from out to out, while the pier columns are placed with their centres directly under the main chords of the bridge, making them 36′ apart from centre to centre, and at right angles to the centre line of bridge.

Among the local difficulties to be met and overcome in this work,

the principal were the small amount of holding ground for the cylinders,—that is, the comparatively shallow depth of material overlying the bed-rock,—and the rise and fall of a tide of 7 ft. found at this point, requiring great care and attention to the clamps and pressure gauge.

The bed of the Schuylkill at the site of the bridge is a micaceous gneissic rock, undulating in surface, with an overlying strata of sand and tough, compact mud, intermingled with gravel and small boulders. Lying directly on the rock, considerable quantities of drift-wood were found, its appearance evincing great age and a long occupation of its present position. The average depth of this bottom material is about thirty feet at the western pier columns, diminishing to only five feet at the eastern pier. At the draw the thickness is about eighteen feet.

The columns are cast in sections, ten feet in length, of the iron before mentioned, 1¼″ thick, with inside flanges, 2¼″ wide by 1¼″ thick, at top and bottom of each section. The flanges are pierced with bolt-holes, 5″ apart, centre to centre, for 1¼″ bolts. The bottom flange is omitted in the section forming the bottom of the column when in position, for greater facility in penetrating the soil. This edge is square, and not bevelled, or brought to a cutting edge, as is generally done, as it is important to retain the full value of the thickness of the column for a bearing surface on the rock. A 10′ section of the 8 ft. column weighs 14,600 lbs., of the 6 ft. column, 10,800 lbs., and of the 4 ft. column, 6,800 lbs.

As many of these sections as the depth of water may require are bolted together, the joints being carefully luted with a preparation of red and white lead and cotton fibre, so as to be perfectly water and air tight. The distance through the bottom material to rock being small, and the depth of water averaging at mid-tide only about 22 ft., five or six sections were sufficient to reach the rock and at the same time to extend some distance above the water surface.

Between the first and second sections, counting from the top, and on top of the column, were placed two diaphragms, or heavy plates of cast-iron (C and D, fig. 1), 1¼ in. thick, and weighing in the 8 ft. columns 2,800 lbs, in the 6 ft. columns 1,600 lbs., and in the 4 ft. columns 783 lbs. The same bolts hold them in position that unite the two sections of the column. These diaphragms (shown in plan in fig. 2) are pierced with three openings each, besides the central trap, or door, E, that is for the air-supply pipe, F, the water pipe, G, and the

equalizing pipes, H or I; these pipes are common iron gas-pipes, 8 in. in diameter. The door, E, varying in diameter with the column from 20″ to 30 in., fits very closely by means of a gum washer, and opens downward; a keeper on the upper side of the diaphragm fastens it when closed. These two diaphragms, with the section of column included between them, form the air-lock, A, which in this work supplants the expensive, cumbersome and independent lock of wrought-iron generally used. The general arrangement of this lock is due to Mr. J. W. Murphy, Contracting Engineer of the bridge. The purpose of the air-lock is to enable the workmen to pass from the normal atmosphere outside the column to the denser atmosphere of the interior, and to prevent the escape of the compressed air while so doing. It is well to mention that lengthening the cylinder by the addition of new sections does not necessitate the removal of the diaphragms; the additional sections are merely bolted to the top of the air-lock, as it matters not whether the lock is under water or not.

To secure the column while the sections are being successively added and bolted together, and to enable it to be brought into position for sinking, a floating support of some kind is necessary. In the bridge in question two ordinary canal boats were used for this purpose, each about 100 ft. long by 17 ft. wide, and drawing 4½ feet loaded. These boats lay parallel to each other, and about 15 feet apart. Resting on them, and extending clear across the boats and the opening, were two heavy "clamps," each clamp formed of three pieces of timber, each 18 in. x 12 in. (X, fig. 6). These clamping beams were shaped on the inner sides to fit the cylinder, and were capable of being drawn together by means of strong iron rods (Y, fig. 6), furnished with heavy nuts and washers at either end. The cylinder is placed between these two clamps, and is tightly clutched by them, when the nuts on the rods are screwed up. In this way the two boats support the whole load until all is ready to let the column slip to its proper place on the river bottom, the rapidity of the downward motion being beautifully regulated by the friction of the clamps alone, the hoisting tackle still being allowed to retain its hold on the cylinder, as a precautionary measure.

Straddling the opening between the two boats, and with its apex immediately over the centre of this opening, is a substantial four-footed shear, or derrick, M, fig. 6, provided with a heavy lifting tackle, O, fig. 6. By means of this apparatus the first section to form the olumn is lifted from the deck and lowered into position between the

clamps, X, and there securely held by tightening up the nuts. The hoisting tackle can then be cast loose, and a next section be lifted and placed upon the one already between the clamps, and the two bolted together. By now cautiously slackening the clamps, we may permit the two sections to slip down into the water until the last put on is, in its turn, between the clamps, and there secure it. We now have sufficient head room for putting on a third section, and the process is repeated until the requisite number are joined together. The bottom edge of the column must not yet be suffered to touch the river bottom, but clear it by a foot or two. When the air-lock diaphragms and their proper pipes are in place we are ready for what is technically called the "sink," that is after the boats, with the column supported between them, are hauled into position and held there by their anchors, and line, distance and exact location accurately established. All preliminaries are then completed, and men stationed at the clamping-rods carefully slacken them and allow the column to slowly sink into the mud, seeing to it that it always maintain its vertical position. The water rises within the column, of course, to the river level, and before men can descend into its depths and the work of excavation commence, this water must be expelled and kept out.

The application of the compressed air is the next step in the process, and to supply this latter power we have, stationed on one of the boats before mentioned, at V, Fig. 6, a "Burleigh Compressing Engine" of nine horse power, made at Fitchburg, Mass. This compressor consists essentially of two plunger air pumps, with 10-inch cylinder and 9-inch stroke; they work alternately and vertically, drawing in the air, through a valve in the piston head, in its downward motion, and by the return stroke forcing it into the reservoir, L, through the pipe, N. To prevent the expansion of the metal in the piston head, from the heat generated in the condensing process, and the consequent jambing of the piston in the cylinder, a stream of water, with a little oil added, is constantly fed upon the piston head, keeping it cool and providing an elastic cushion to act upon. The reservoir, L, in which the air is compressed and stored, is 22 feet long by 2 feet in diameter, ¼-inch boiler iron, and was originally a steam boiler; it is provided with pressure gauge and safety valve. This reservoir will supply the column with compressed air for one-half hour, did any accident happen to stop the pumping machinery, giving the workmen inside that time in which to escape. In the old method, when the air was pumped directly into the cylinder without the in-

tervention of a storing reservoir, even a momentary stoppage of the engine endangered the lives of all in the working chamber.

From the reservoir, L, the compressed air passes through the common gum and canvas hose, P, four inches in diameter, into the supply pipe, F, and discharges immediately into the working chamber, B, below the floor of the air-lock or lower diaphragm, thus passing through the air-lock, A, but having no communication with it. The pipes, F and G, pass through stuffing boxes in the top and bottom of the lock.

When we wish to force the water out of the cylinder, the lower door, E, must be first securely closed, cutting off all communication with the outer air. Air compressed to a density sufficient to counterbalance the water column in the cylinder is then let in from the reservoir, and a very few minutes will be sufficient to eject all the water from the inside of the chamber, B, forcing it out at the bottom, and to replace it with the compressed air, which, from this time forward, is being steadily pumped in—all excess and air vitiated by the breathing of the men escapes from under the lower edge of the column, and rises in bubbles to the surface of the water. When the material to be penetrated is a tough compact mud, impervious to water, the water inside cannot be forced out under the bottom edge of the cylinder, and we must have resource to the water-pipe, G. This pipe extends from the bottom of the cylinder, through the air-lock, to the top, where it ends in an elbow provided with a stop cock, J. There is also a slip joint near the bottom for lengthening the pipe when necessary. When the stop-cock, J, is opened, the excess of pressure on the surface of any water there may be in the cylinder, B, will force it up through this pipe and out over the top of the column, projecting it with great violence.

A fact, perhaps, worth notice, is that the *actual* pressure required to lift a column of water a certain height through this pipe, is always *less* than the calculated pressure. The supposition is, that the expansive action of the compressed air in the pipe (for a considerable quantity escapes with the water, being let into the pipe, G, through a hole about ¼″ diameter, purposely left at the slip joint, at a point about 15′ above its lower end) assists in the lifting process. With an indicated pressure of 17 pounds in excess of the atmosphere, we raised water 58 feet.

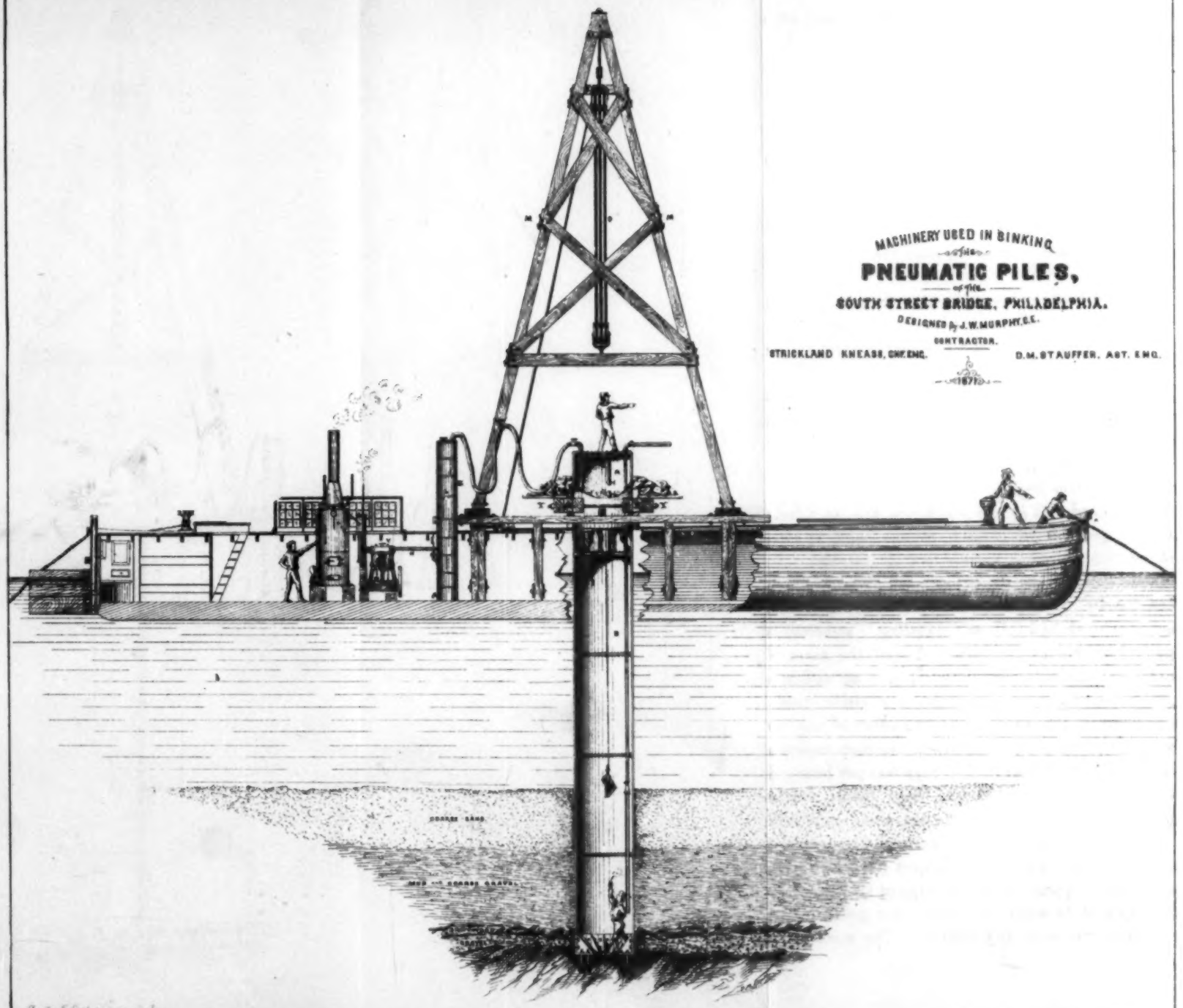
With the water forced out and kept out by the presence of the condensed air, all is ready for the entrance into the column of the workmen; all that part of the column below the floor of the "air lock,"

or the diaphragm, D, is now filled with compressed air, and the problem to be solved is to enter it from the outer air and, at the same time, prevent this condensed air from escaping. This is accomplished as follows: The men descend into the lock, A, by a rope ladder, Z, through the upper door, E, and when in, close the door after them and fasten it; the atmosphere of the air-lock is still of the normal pressure; but to enable them to pass into the denser atmosphere, the air in the lock must be equalized in pressure with it. To do this, they open carefully and very slowly (if it is a first experiment) the equalizing valve, I, in the lower diaphragm, and allow the compressed air to ascend and gradually fill the lock chamber, until the pressure is equal in all parts of the column.

This process consumes more or less time, according to the intensity of the pressure and the experience of the men. The pressure upon the drum of the ear by the compressed air is very painful to the new man, and this dense air must be let in upon him slowly. Three minutes will pass men accustomed to the work through the air-lock, under a pressure of 22 pounds in excess of the atmosphere. When the equalization of pressure is completed, the lower door, E, can be opened, a rope ladder lowered to the bottom, the men descend, and the actual work of excavation begins.

To remove the mud, sand and gravel which now fills, to a considerable height, the lower part of the column, canvas bags, as shown at Q, are used, each containing about a cubic foot of material. In the larger columns, five to six men constitute one working gang; two men fill the bags at the bottom, while the remainder hoist them into the air-lock by means of a block and fall, or "gantling," attached to the bottom of the upper door, E, and stow them around the sides of the lock. Under favorable circumstances, these six men fill and hoist 20 bags per hour, equivalent to about four-fifths of a cubic yard. In mid-summer, on account of the heat inside, the effect of the sun on the iron cylinder, and the compressed air itself, the men cannot work quite so fast; they will average four or five bags less per hour. When working in sand or gravel they can fill the bags faster than when working in tough mud, but as they consume the same time in hoisting, the actual amount of work per hour is about the same. The quantity of material extracted per hour is subject to great variation; driftwood or boulders may appear under the edge of the cylinder, and they must be cut away with hammer and chisel, at a great expense of time, before the columns can sink any further. The work is pushed

Fig. 6.



MACHINERY USED IN SINKING
of the
PNEUMATIC PILES,
of the
SOUTH STREET BRIDGE, PHILADELPHIA.

DESIGNED by J. W. MURPHY, C.E.

CONTRACTOR.

STRICKLAND KNEASS, CHF. ENG. D. M. STAUFFER, ASST. ENG.

1871

Scale 5 feet to one inch.

Photo-Zincography by F. A. Wenderoth, 933 Arch Street, Philadelphia.

Print by J. H. Camp, 610 Jayne Street, Philada.

forward day and night, the workmen being divided into three gangs, each gang working four hours at a "shift," unless the depth is great and the pressure excessive. When their time is up, and the men are ready to go out, all ascend into the "air-lock," close the lower door, E, tightly, and reversing the process by which they entered, allow the compressed air in the air-lock to escape outside by opening the equalizing valve, H, when the atmosphere of the lock is once more reduced to the normal pressure, the upper door, E, can be opened, and the men are once again in the open air. The bags of *debris* are emptied into the river, and the relieving gang enter and repeat the process.

If the workmen have completely emptied the cylinder to its lower edge before coming out, they make a "sink," as it is called, before the next gang enters. This is done by cutting off communication between the reservoir, L, and the cylinder, B, by shutting the cock, K, and by allowing the compressed air in all the columns to escape through the equalizing cock, I. The water will immediately flow in under the lower edge of the column, and, rising within, fill it. The mass of metal, no longer upheld by the upward pressure of the condensed air, obeys the law of gravitation, and sinks a fresh distance into the soil, and after the water is again forced out, is ready to be excavated as before. The rush of water under the bottom edge, of course, loosens up the material and facilitates the sinking. Sometimes in penetrating tough mud, impermeable to water, the water cannot come in even when the column is emptied of the compressed air; in such a case, the weight of the metal only will act, and the depth sank be only a few inches. In sand and loose gravel, however, the "sink" will average five feet.

This alternate filling and emptying of bags, and the slow settlement of the column, continued until the bed-rock on which we intended to found our work, was reached. Where this rock sloped it was brought to a level surface by chisels, and all shally and rotten portions removed. This levelling process was to prepare the rock for the reception of the foot pieces, shown at R, Fig. 3—an innovation first introduced, I believe, by Mr. J. W. Murphy, Con. Engineer of the bridge, and made necessary there by the comparatively slight depth of the holding ground. These brackets or foot pieces are in sections, and extend clear around the whole inner circumference of the cylinder, requiring sixteen in each 8-foot column, twelve in the 6-foot column, and eight in each 4-foot column. They are made of cast iron 1¼ inch

thick, and weigh, in the larger columns, 340 pounds each; in the smaller, 183 pounds each. Each bracket is fastened to the cylinder by four 1¼ inch tap bolts, and to the rock by four bolts 18 inches long, with fox wedges at lower end, and thread and nut on top. They undoubtedly add much to the stability of the work; their holding power has already been severely tested.

When the column is once thus secured to the rock, we may consider the major portion of the work done, and it only remains to fill it carefully with common rubble masonry laid in hydraulic cement. The material for laying the first ten feet of masonry must necessarily be passed through the air-lock, as were the men. Water to mix the cement is pumped in against the pressure in B through the pipe, G, by attaching the hose of a force pump to its upper extremity. When the first ten feet of stonework is in place, extending to and in a manner held down by the projecting inside flange at the top of the bottom section, we may consider the column effectually sealed against the entrance of water from below, and it will be safe to let off the pressure and remove the diaphragm doors, completing the remainder of the work as in an open well.

When all the cylinders are in position the tops will differ in level; some will have descended deeper than others before finding the rock, and extra sections must, therefore, be cast of a length necessary to bring them all to the height required by the plan of the bridge.

As a precautionary measure, a workman is always stationed on guard outside, and on top of the cylinder, whose duty it is to listen for and answer all signals from the men within the column, and to render immediate assistance in aiding the men inside to escape, should any accident occur. Communication is kept up between this guard and the workmen in the working chambers by a telegraphic system of taps with a hammer or some iron instrument on the sides of the cylinder. The following is the "code" ordinarily used:

One blow signifies, "Open water-cock."
Two " " "Shut " ."
Three " " "Attention."
Four " " "We are coming out."
Five " " "Water going down."
Six " " "Water still going down."
Seven " " "Water stops running."
Eight " " "All right."
Four blows, in pairs of two, signify "Danger! Come out immediately."

The signals 5, 6 and 7 refer to the forcing out of such water as may leak in while the men are working. All signals from the inside are repeated by the watchman to show that he understands them.

There is one important effect of the upward force exerted by compressed air that must not be neglected, but, on the contrary, carefully guarded against; and that is the danger of lifting the column bodily, when the pressure per square inch, acting upward on the lower diaphragm, *more* than counterbalances the weight of metal in the cylinder, and the friction on the sides of the column due the material through which it is passing. To overcome this difficulty in the South St. bridge, the heavy clamping timbers, X, Figs. 6 and 7, were raised clear of the boats, and fastened to the cylinder itself, by tightening the clamping rods, as shown in Fig. 6. Upon these beams a platform was placed, which was loaded with a sufficient quantity of stone to overcome any tendency to rise, and augment, as well, the effective weight when a "sink" was made. This same end was attained in the last 8-foot column sunk, by building a platform of heavy timbers inside of the cylinder, two sections or twenty feet below the floor of the air-lock. This platform was weighted with about forty tons of stone; a strong wooden shaft, three feet square, furnishing a means of access to the lower portion of the column.

The time occupied in sinking the pneumatic columns at this place, varied with their position and the quality and quantity of the bottom material. At the draw, with an average depth of eighteen feet of sand, mud and gravel, it required about eight days each from the time of applying the air pressure to its removal, with 10 feet of the masonry in place. At the west pier, with thirty feet of mud, sand and boulders, thirty days were necessary; while at the east pier, where there was only about six feet of gravel overlying the rock, twenty days were consumed. This delay was caused, however, by the great pitch of the rock; it sloped nearly four feet in the diameter of the column. In nearly all the columns, levelling off the rock-bed, drilling the holes for the fox wedge bolts, and attaching the foot pieces, consumed by far the greater amount of time. A 4-foot column was generally sunk and cleared through eighteen feet of mud, sand and gravel in twenty-four hours. The work at the South St. bridge was pushed forward winter and summer, the flow of ice not interrupting in the slightest degree the progress of the work. The compressor engine was started on the first column Oct. 4th, 1871, and on Aug. 29th, 1872, the last of the thirteen columns was in place.

The effect of the compressed air upon the men is nearly always severe the first time they encounter it, but a little experience generally removes all unpleasant sensations. The greatest actual pain felt arises from the abnormal pressure upon the drum of the ear. The tubes extending from the back of the mouth to the bony cavities over which this membrane is stretched, are so very minute that compressed air cannot pass through them with a rapidity sufficient to keep up the equilibrium of pressure on both sides of the drum, for which purpose the tubes were designed by nature; the excess of pressure on the outside causes the pain. These tubes can be distended and the pain relieved, by the act of swallowing, or by closing the nostrils with the thumb and forefinger, shutting the lips tightly and inflating the cheeks. Either action facilitates the passage of the air through the beforementioned tubes, and establish the equilibrium desired; but the relief is only momentary, and the act must be repeated from time to time, as the pressure in the air-lock increases. This pain is only felt while the air in the "lock" is being "equalized" or compressed. When the lungs and the whole system are filled thoroughly with the denser air the pain passes away, and the general effect is rather bracing and exhilarating than otherwise. You breathe freer, your lungs are expanded, and the whole muscular system seems capable of extra exertion. From the excess of oxygen breathed, you are, in fact, living a physically "fast life;" but the novice, like the "fast liver" of the world at large, often pays rather dearly for his momentary strength; for, on getting outside a reaction sets in, with a general feeling of prostration, lasting, in my own case, at least nearly a whole day after the first two or three encounters with the compressed air. The laborers, by daily experience, soon overcome this feeling, and in the majority of cases feel no bad results, either while at work or afterwards.

The extreme limit or greatest depth at which men can labor, without material injury to themselves, has not yet been reached in works of this nature. Captain Eads, in the process of founding the piers of the St. Louis bridge, has sunk his caissons considerably over one thousand feet below the surface of the Mississippi—a depth never before obtained—and yet by shortening the hours of labor from four hours to one hour, as the pressure increased, little trouble was experienced by the men. Even delicate ladies, according to the Official Report of Capt. Eads, remained in the caisson nearly an hour, without feeling any marked ill effects from the extreme pressure. Out of

the 350 men who, at different times, performed duty in the air chamber at St. Louis, 35 were seriously affected by this unnatural pressure. Of these, twelve died; but the verdict of skilful physicians gave, in more than half the cases of death, totally different causes, though admitting that the effect of the compressed air was the exciting cause. Persons of weak lungs or of intemperate habits have no business there; and even a severe cold in the head, by stopping the eustachian tubes with mucus, will make it impossible to relieve the pain on the membrane of the ear while passing through the air-lock. In such a case there is danger of rupture to the drum of the ear, and the party should be let out immediately.

Owing to the excess of oxygen in the atmosphere of the column, combustion is, of course, more rapid than in air of the normal pressure; a candle is consumed in one-half the time inside, but burning with a flame nearly twice as high gives more light, and a less number is necessary for illuminating purposes. Fire must be carefully guarded against, as even the woolen clothing of the men is no safeguard—it will burn furiously when once ignited. Fire will, too, in this atmosphere, penetrate the most minute crevices. In one of the columns of the South street bridge, the luting of red lead between the sections was accidentally ignited, and though the exposed area was exceedingly small, it burned out that combustible material completely, nearly suffocating the workmen with the fumes of the paint. The excessive amount of smoke thrown off by the burning candles is another source of annoyance. The particles of unconsumed carbon float in the atmosphere, and are breathed by the men, coating the nostrils with its sooty deposit. In larger works of this nature, where roomy caissons are used, other methods of lighting are feasible. At the East River Bridge ordinary burning gas was employed with good effect.

The superiority in stability and duration of tubular foundations over solid piers of masonry, is a question we will not debate; but of their greater economy in time and money, under difficult circumstances, I think there can be little doubt. Their greatest value is apparent, however, in the Western rivers, where the engineer must contend with deep beds of quicksand, liable to scour out to the very bed rock in a rise of the river, undermining and washing away any structure not based on that rock. To attempt to found a bridge, in such a location, by piling cribs or coffer-dams, would be a hopeless task; and it is under just such conditions that the great value of the Plenum Pneumatic Process asserts itself.

We might mention, in closing our article, that the "Plant" used by Mr. I. W. Murphy in sinking the pneumatic cylinders of the South street bridge, is worthy of special notice, from the fact of its combining a severe economy with all the requirements for effective work. The two canal boats, strengthened somewhat by inside bracing, the derrick, the clamps, and one Burleigh Compressor, were about the only appliances used, and they did the work well.

THE OVERFLOW OF THE MISSISSIPPI RIVER.

No. 2.

By D. S. Howard, C. E.

The first step towards reform is a consciousness of its necessity. The Southern papers seem to be united now in condemning the levee system of protection against the overflow of this river, and are discussing the subject of disposing of the surplus waters of the freshets by canals and additional outlets from the lower river.

It is well to take into view every possible means of accomplishing so important an object, before adopting a new system, and to look sharp at every possible objection to every proposition offered. Notwithstanding the old system may be the worst, any new one proposed to supersede it may not be the best; therefore our vision should not only be extended in proportion to the importance of the subject, but every remedy discovered should be subjected to the severest scrutiny. Will the outlet system bear it?

If the outlets are ample for the highest freshets, they will accomplish one object (so would the dykes, if made high enough and strong enough)—the same absence of overflow would follow. The next question that arises is, what would be the relative expense? which can only be determined precisely by a very expensive survey. There are other considerations, however, which may settle the question between these two systems without going into a survey of the outlets. One is, what effect would they have on the bar at the mouth of the river? If they are made navigable, as proposed by some of the papers, and require feed-water from the river in low-water season, it is very plain that navigation at the mouth of the river must suffer at all times, in proportion to the amount of water used by the lateral outlets. This would seem to settle the question between the levees and the lateral navigable canals.

If the beds of the outlets are above low-water they will be of little

service as navigabe channels, but might be made wide enough to serve the purpose of levees. Then the question would be, what effect would *they* have on the bar at the mouth?

If the quantity of water in the river at the time of freshets be diminished, the location of the bar will be farther up the stream. If the sediment be diminished, the bar will be diminished in the same proportion. This raises the question, what proportion of the sediment would the outlets divert from the bar? and what would be the quality of it?

It is evident that whatever sediment is heavier than water will continue to sink, from the time it is free from the disturbing cause until it reaches its resting-place. It is also evident that the heaviest part of the sediment would be contained in the water below the level of the beds of the outlets. Therefore the outlets could only divert their proportion of the quantity and quality of sediment in the river above the level of their own beds, a large part of which would probably pass over the bar into the salt water, and finally find rest on the Gulf beach.

As the outlets are subject to the same laws that first created the necessity for dykes along the river, some measures to prevent overflow on the outlets as well as the river would soon be required. Sediment would have the same tendency to settle in one as the other, and in all as it ever had in the river. If the outlets are allowed to overflow their banks, the banks will rise with the beds, until the condition of the outlets becomes favorable to the formation of crevasses, in high freshets, the same as that of the river before the dykes were built, and which rendered them necessary. In evidence of this, we have only to look at any or all similar rivers, such as the Nile, the Ganges, the Danube, &c., whether dykes have been in use or not. The extension of their delta requires the elevation of the bed and banks faster than the decay of vegetation alone can elevate the country around. Thus is produced a favorable condition for crevasses, which is the cause for a plurality of outlets to all such rivers.

Another view of the outlet system is, to make the river large enough and straight enough to dispose of the freshets without lateral outlets. This plan would afford protection from overflow at less expense, at the same time improve the navigation. The great objection to this, as well as the whole outlet system, is the constant expense required to continue its usefulness.

No remedy for any evil that does not reach the cause can be of much

value. We must depart from the usual custom of confining our contemplations to the evil we would prevent, and trace it to the most remote cause we can have any control over. The cause of the overflow of the lower river is a concert action of freshets in its thirty-two principal tributaries, or a majority of them, which does not happen every year, consequently there is an annual variation of the freshets in the lower river. The cause of this variation is a more or less universal rainfall on the 300,000 square miles of water shed of these rivers. We can have no control over the rainfall, of course, but we can obstruct the flow of its waters to the lower river in a manner that will interrupt the tributary freshets so much as not only to render them harmless, but the timely arrival of their surplus waters, in consequence, will be of almost inestimable value to the navigation.

This may be done by the reservoir system, which has been considered and discussed so much in former volumes of this Journal, with a view of improving the navigation, for which it is equally well adapted, that it is unnecessary to enlarge upon it at this time, further than to say that figures may be made, without the expense of a survey, that will show, in all probability, the expense of this system to be less than either of the others mentioned. While the levee and outlet systems have only a temporary effect on the overflow, the reservoir system has a favorable permanent effect on the navigation, improves and adds to the water-power on the upper streams, by preventing their destructive freshets, as well as the overflow of the lower river.

N.B.—Errata for Paper No. 1: in Vol. LXII, Oct., 1871, No. 4, page 253, 7th line from bottom, for promoting read preventing; also, on page 256, 7th line from bottom, for promoting read preventing.

Richmond, Va., 4th Aug., 1872.

A New Combination for the Battery.—M. Gaiffe, before the French Academy, recommends the following elements for obtaining a galvanic current of great constancy. It is composed of a vessel in which is plunged a sheet of lead and another of tin. The lead sheet descends to the bottom of the vessel; that of tin is one-half shorter. At the bottom of the vessel is placed a bed of minium. The exciting liquid is water and chlorhydrate of ammonium in the proportions of 10 to 100. The electro-motive force of this combination is stated to be about one-third that of the Bunsen. Its interior resistance is weak and constant, and the resultant compound does not materially change the conductivity of the liquid. Its constancy is said to be very great.

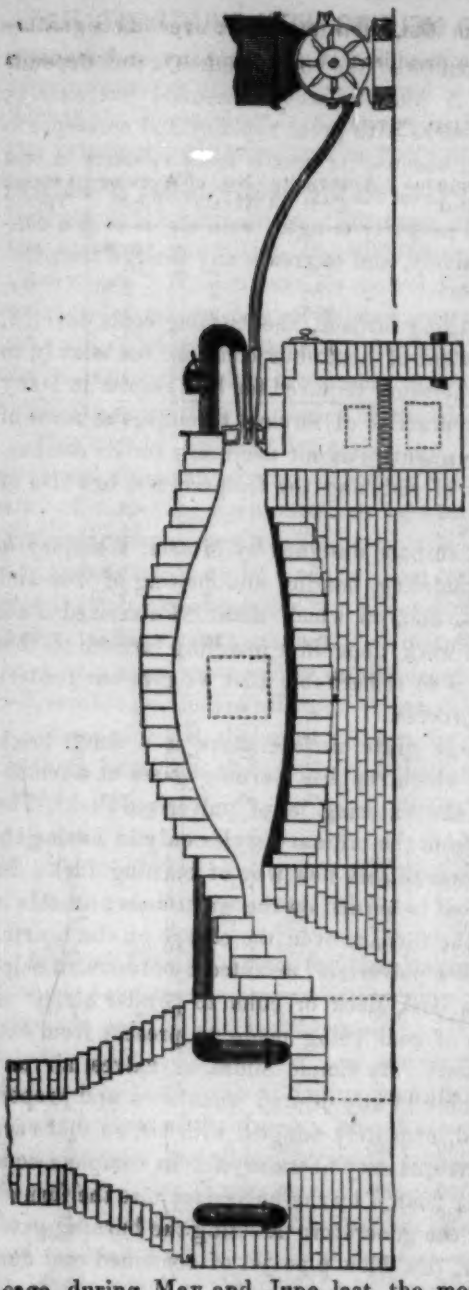
PUDDLING, HEATING AND MELTING WITH PULVERIZED FUEL.

The rapidity and completeness of the combustion of a fuel depends upon its exposed surface. A block of wood consumes but slowly; converted into shavings, it burns with great rapidity and corresponding increase of temperature, because its heat is made effective in less time. A cubic inch of coal presents six square inches of surface; reduced to fine powder, and properly mingled with air, it is in a condition to burn almost explosively, and to create any desired temperature in a furnace.

In the ordinary grate-burning furnace, the burning coals develop, of course, their full equivalent of heat, but consume too slowly to raise the furnace to the temperature required for best results in many operations. The universal practice of forcing through the mass of coals on the grate twice the quantity of air necessary for its combustion has the effect, not only of reducing the temperature, but also of causing great waste of fuel.

Our illustration shows a furnace designed by Messrs. Whelpley & Storer, of Boston, for the puddling, heating and melting of iron and steel, the reduction of ores, etc., to which their "Pulverized Fuel Process" is applied. The work done in a puddling furnace of this kind, as certified to below, is so remarkable that we give our readers a brief description of the process.

In place of the usual large grate surface there is a small brick chamber, or gas generator, which supplies burning gases at a temperature sufficient to ignite the entering jet of pulverized fuel. The rest of the furnace differs from the ordinary styles only in having its inner lines shaped to conform to this new way of burning fuel. In the ordinary furnace the coal is burned on the grate bars; in this it is burned in the body of the furnace over the charge on the hearth. At the rear of the furnace is a pulverizer, invented by Messrs. Whelpley & Storer, which reduces coal, slack or culm to powder almost as fine as smoke (a cubic inch of coal being made to present from 400 to 500 square feet of surface.) By simple slides, or valves, air and coal are fed into this machine in any desired quantities and proportions. Reduced to dust and intimately mingled with air, so that each particle is surrounded by the quantity necessary for its complete combustion, the coal is blown or floated by the pulverizer into the furnace through a narrow slot over the generator. Meeting the burning gases arising from the generator, this blow pipe jet of combined coal dust



and air instantly takes fire, and, moving forward, fills the body of the furnace with a most intense flame. The combustion of the coal is so complete in the furnace that no smoke escapes from the stack, but only a light cloud of fine ashes. All the heat is utilized in the furnace.

In the bottom of the stack are cast-iron pipes, through which air is urged by a blower. This current of air, after the furnace has been working two or three hours, becomes heated to about 600° Fahr., and is conducted by a jacketed pipe into the furnace through an opening just over the pulverized fuel entrance. A turn of a valve will so regulate the supplies of coal and air that a flame of any character desired may be produced, whether neutral, reducing or oxidizing.

We understand that the cost of the furnace and its appliances is but a few hundred dollars greater than that of an ordinary one of the same capacity.

At a practical trial of this furnace, made at the Union Rolling Mills, Chicago, during May and June last, the most satisfactory results were

reached, as will be seen from the following report over the signature of Mr. Wm. Chisholm, vice-president of the company and manager of the Works:

DAY "TURN."

	Iron Charged	Yield.	Bituminous Coal.	Anthracite Coal.	No. of Heats.	Working Time.	Average Time.
						H. M.	H. M.
May 30	2624	2625	1755	220	5	10.	2.
" 31	1060	1145	655	88	2	3.30	1.45
June 1	2650	2540	1246	220	5	9.	1.48
" 3	2650	2605	1380	220	2	10.	2.
" 4	2650	2640	1275	220	2	8.30	1.42
" 5	2650	2680	1275	220	2	7.45	1.33
	14284	14295	7586	1188	18	48.45	10.48

NIGHT "TURN."

						H. M.	H. M.
May 30	2650	2690	1190	220	5	9.	1.48
" 31	2650	2735	1615	220	5	11.20	2.16
June 3	2120	1940	1360	176	4	9.40	2.25
" 4	2650	2560	1445	220	5	9.30	1.54
" 5	2650	2590	1275	220	5	9.30	1.54
	12720	12515	6885	1056	24	49.00	10.12

DAY "TURN."

	Castings.	Iron Charged.	Yield.	Bitumin'us Coal.	Anthracite Coal.	No. Heats.	Working Time.	Average Time.	Scrap.
							H. M.	H. M.	
June 6	150	2500	2735	1360	220	5	8.30	1 42	90
" 7	150	2500	2700	1445	220	5	10.	2.	
" 8	150	2500	2725	1445	220	5	10.	2.	
" 11	90	1500	1460	935	132	3	6.	2.	145
" 12	150	2500	2625	1530	220	5	10.20	2.04	75
" 13	66	1000	1100	850	88	2	5.	2 30	105
	756	12500	13345	7565	1110	25	49.50	12.16	405
	13256								

NIGHT "TURN."

							H. M.	H. M.	
June 6	150	2500	2740	1445	220	5	10.	2.	150
" 7	120	2000	1910	1190	176	4	10.	2.50	90
" 8	60	1000	1100	595	88	2	5.	2.30	70
" 11	150	2500	2580	1245	220	5	10.	2.	90
" 12	120	2000	2130	1190	176	4	9.	2.30	
	600	10000	10360	5665	880	20	44.	11.30	390
	10600								

RECAPITULATION.

	Iron Charged. lbs.	Iron Yield. lbs.	Coal. lbs.		No. of Heat.	Time. H. M.
Totals,	14284	14295	7586 1188	8774	18	48.45
	12720	12515	6885 1056	7941	24	49.
	13256	13345	7565 1110	8675	25	49.50
	10600	10360	6665 880	6545	20	44.
	50860	50515		31935	87	190.35

Total loss on iron, from pig to muck bar, three-fifths of one per cent.

Total coal used per ton, 1260 lbs.

The coal used is the waste or screened portions of both bituminous and anthracite, the bituminous, in this instance, being from Indiana mines, and not so strong as Erie or other Pennsylvania coals. The coal as used costs in this market not to exceed $3 per ton.

In many instances during the above trial the iron was balled and ready to draw in less than one hour and thirty minutes, the balance of time as charged in report being occupied in waiting on the other furnaces, a scrap furnace and flange furnace having the right to rolls in preference to all others. While waiting on them the consumption of coal was the same as while puddling.

The consumption of ore and scale is about the same as in an ordinary furnace.

During the trial the weather was excessively warm, and the men were unable to work full *turns*, and probably to not as good advantage as in more favorable weather. Doubtless the above is a fair report of what the furnace would perform daily.

[Signed] Wm. Chisholm,
Vice-President and Manager.

Mr. Chisholm also furnishes the following figures:

In puddling this iron in an ordinary furnace the loss from pig to muck bar is about ten per cent., muck bar being worth about $65 per ton. The coal used, *Indiana block*, costs at the mill $5 per ton. The ordinary furnace requires about one and one-half lbs. of this coal to each pound of iron puddled.

Taking these figures, the saving, as shown by this report, on each ton of muck bar made in the Whelpley & Storer furnace would be as follows:

Ordinary Furnace:		
3000 lbs. Coal, at $5.00,		$7 50
10 per cent. loss on Muck Bar, at $65.00,		6 90
		$14 00
Patent Furnace:		
1260 lbs. Coal, at $3.00,	$1 89	
Say 1 per cent. loss on Muck Bar,	65	
		2 54
		$11 46

Messrs. J. W. Robinson, Jas. Hollis, Jno. Clark and D. E. Williams, practical puddlers, who witnessed the operation of this furnace for the first time at the Union Rolling Mills, have presented to the patentees the following voluntary testimonial:

Having had practical experience in working the puddling furnace (using pulverized fuel) recently constructed at the Union Rolling Mills in this city, we are happy to certify to its merits: The average consumption of Indiana coal screenings per ton of iron puddled has been only about 1200 lbs.; the weight of puddled bar equals weight of iron changed; quality of iron as shown by fracture fully equal to best made in mill; time of heats, one hour and thirty minutes; labor of working not more than ordinary furnace, perhaps less, as there are no grate bars to clean; durability of furnace, equal to any we have ever seen worked. We are of the opinion that a double puddling furnace, constructed on this plan, would show even greater economy in fuel than this single furnace.

Mr. Storer has quite recently patented certain modifications to the furnace above described, with the object of making a deodorizing furnace, for disposing of the refuse matter of slaughtering, rendering, bone-boiling and other similar establishments, in such a way as to avoid the pollution of the air with noxious and offensive gases.

The plan adopted is to burn or dry the refuse animal matter, and to decompose and deodorize the resulting gases by subjecting them to a high temperature, and a contact or mingling with coke or coal, and in some instances also with sulphurous gas. We shall reserve for a future number of the "Journal" a detailed description of its parts, and will simply reproduce here an account, abstracted from a local journal, of the operation of one of them at an extensive slaughtering and pork-packing establishment in Chicago:

The establishment of Messrs. Reid & Sherwin was visited yesterday afternoon by a large number of gentlemen engaged in the pack-

ing business, the Police Commissioners, and several others interested in the success of the enterprise, to witness a trial of the apparatus for utilizing offal matter and gases, and the trial proved eminently satisfactory,—not only entirely destroying the refuse matter and noxious gases, but absolutely rendering them a matter of commercial value.

During the last seven years there have been over sixty patents granted in reference to this matter, of which a few are now in operation, but none of which have as yet succeeded in doing the work demanded by strict sanitary regulations. Messrs. Whelpley & Storer, the inventors of the system of deodorizing tested yesterday, have been engaged for the last ten years experimenting upon the different methods of burning coal to produce the maximum of heat with a maximum expenditure of fuel, their experiments being protected by patents.

The present process consists of a peculiarly constructed furnace, with hot-air chamber, in which the fuel is burned, pulverized as fine as smoke. By one operation all tank stuff of the packing-house, the manure, and even the escape steam from the tanks, which no condensers have hitherto succeeded in rendering inoffensive, are absolutely deodorized. The manure is used as fuel in one of the fireplaces; the steam from the tanks, being decomposed by the heat of the furnace, passes off in inodorous gas, while the tank stuff and all refuse animal matter is dried in the body of the furnace to a condition best fitting it for a fertilizer; the 60 to 80 per cent. of moisture in the refuse matter is evaporated without the slightest escape of effluvious odor, while the solid matter, with all its valuable fertilizing properties, is retained.

On our visit yesterday, which was the fifth day it had been in operation, our attention was directed to the fact that, although this was a small furnace, erected simply to demonstrate the feasibility of the operation, yet it was working nearly a ton per hour of tank offal, converting it into a good fertilizer. The utility of this as a matter of economy to Messrs. Reed & Sherwin may be appreciated when we say that it had formerly cost that firm about $75 per day to haul this refuse matter to remote parts, and by the simple working of this furnace, they are able to utilize it to a fine powder, absolutely free from offensive smell, and worth, for fertilizing purposes, from $16 to $20 per ton,—so that they not only get rid of the offensive material at a cost of nothing, but derive a handsome revenue from utilizing its properties.

The furnace smoke stack, through which all the gases escape, is but 25 feet high, and by standing upon a platform near its top, we are enabled to testify that we could perceive no unpleasant smell or stench. The furnace used at present is ample for all the use required of it, but may be enlarged to any capacity. The cost of running it will be between $10 and $15 per day, but the revenue derived from the sale of fertilizing material will far exceed that amount.

BELTING FACTS AND FIGURES.

By J. H. Cooper.

(Continued from page 177.)

Mr. Benjamin Clement, M. M., of the Calico Print Works, Dover, N.H., communicates the following:—"For estimating the horse-power of belts, I use the formulæ of Hoyt Bros., of New York, which are: $W = \frac{36{,}000 \times \text{H. P.}}{V \times F \times 6}$ and $\text{H. P.} = \frac{\frac{1}{2} S \times V}{36{,}000}$ in which W = width of belt in inches, V = velocity of belt in feet per minute, H. P. = horse-power, S = square inches of belt in contact with smaller pulley, F = length of belt in feet in contact with smaller pulley. The above supposes each square inch of belt in contact to raise ½ lb. one foot high per minute.

"All other things being equal, the area of contact will govern the driving power.

"Castor oil drainings are the best for leather belts.

"The grain side in all cases should go next the pulley.

"My practice is to give $\frac{5}{16}$" per foot of breadth for the convexity of pulleys.

For covering pulleys I use a mixture of three pints of glue made up with vinegar, to which I add a common tea cup full of Venice turpentine.

"We have at these works an 18" single belt driven by a pair of bevel gears. The belt pulleys about 30 ft. between centres, 6 ft. in diameter, and make 100 revolutions per minute. The gears are 2½" pitch, 7" face, and have 48 teeth; the driven one wooden cogs. According to the relative wear I consider them well balanced.

"We have a double leather belt 18" wide, 35 ft. between centres of pulleys; the driven pulley 5 ft. 10" diam., running 116 revolutions per minute, which has given off 130 horse-power by actual tests with indicator applied to the engine.

"This is a belt velocity of 2,117 ft. per minute, and a surface velocity of 24·42 square feet of belt per minute per horse-power.

Water-proofed Leather Belting.—A Company in Philadelphia is at present very successfully engaged in water-proofing various materials by patent process. They operate upon lighter fabrics of all kinds, and also upon leather, and claim to add considerably to the durability and efficiency of belting so prepared. The belting is rendered perfectly water-repellant, and can therefore be employed under circumstances where the ordinary leather would rapidly stretch and become worthless, namely, whenever it is exposed continuously to the wet.

A line of belting thus prepared has been for some months employed in transporting from the bed to the shop, damp clay for subsequent working, the clay being simply heaped upon the belt, and thus traversed. The water-proofed belt has thus far, we are told, not appreciably stretched or deteriorated, which would indicate that the process is a successful one and of much practical value.

The process, from the account of one who is conversant with the operation, is stated to be as follows:

"Leather bands, having the joints cemented and riveted in the usual manner, are steeped in an alkaline solution, which permeates them and forms a coating in the surfaces of the cells and pores.

"By the subsequent treatment in a solution of metallic salts (sometimes accelerated by pressure), the coating is rendered insoluble and repellant to water.

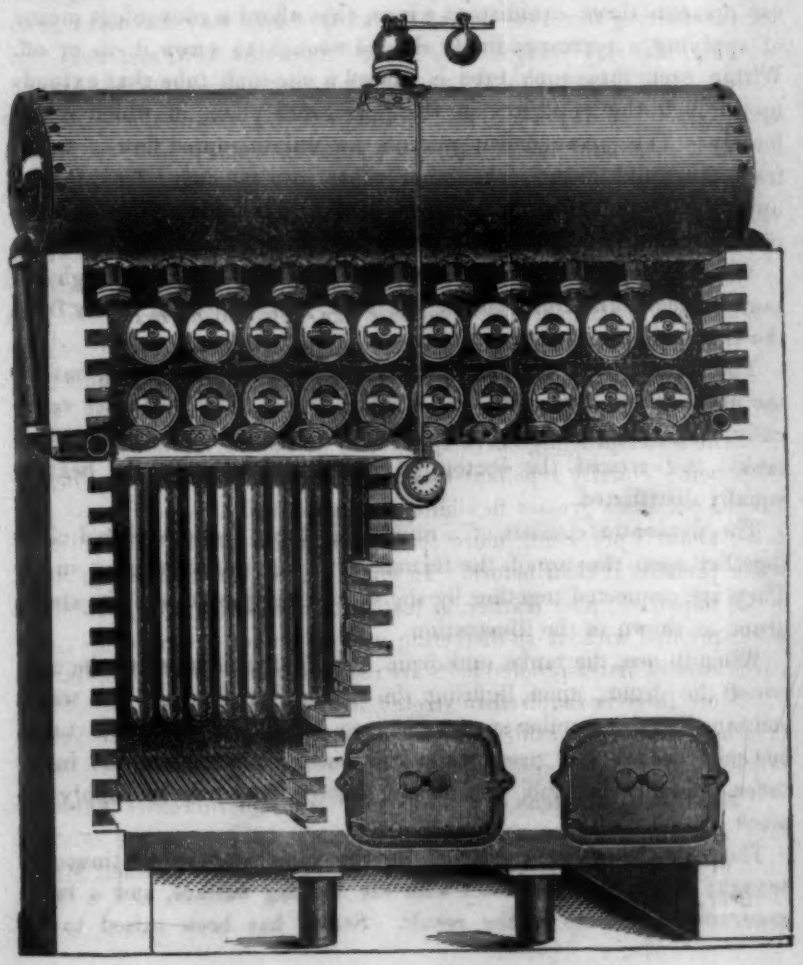
"The water-proofing effect appears to be thorough; newly cut surfaces being equally repellant to water with the original. Belting so treated possesses greater flexibility and improved adhesion to the pulleys; about 5 per cent. more force is requisite to slip a band after water-proofing it than before. In good leather the tenacity of fibre is not impaired; poor leather, or leather of unequal texture, cannot be water-proofed without so distorting it as to render it unsaleable; the purchasers of water-proofed belts are reasonably sure of good material.

"More force is required to stretch the belting after water-proofing than before, and a considerable degree of elasticity is imparted by the process.

"The belting shortens or shrinks in length and increases in width, thus showing a tendency during the process to resume the original form of the leather before the stretching operation of the belt manufacturer."

DESCRIPTION OF THE WIEGAND SECTIONAL STEAM GENERATOR.

The Wiegand steam boiler is composed of a series of separable sections of uniform size and power, placed side by side, and united to one feed-pipe and one steam-drum. Each section is composed of a strong, steam-tight double tank, five feet four inches in length, ten and one-half inches wide, and twenty-four inches in height,—twenty-four lap-welded wrought-iron tubes (made of the best charcoal flue iron), of three inches external diameter—with cast-iron cups or caps to close their lower ends; a corresponding number of wrought-iron inner tubes of one-inch internal diameter, one return bend for connecting the tank to the feed-pipe; and the necessary bolts and nuts



for making the connections to the tank. The bottom of the tank has two rows of apertures, twelve in each row, into which the three-inch tubes are screwed. The tank is divided into two distinct compartments by a perforated plate, placed a short distance above and parallel with the bottom. The plate has two rows of apertures corresponding to the bottom of the tank, for the insertion of the one-inch inner tubes. The cap or cup which closes the lower end of the three-inch tube is five inches in length, and is cast cylindric at the part that screws upon the tube, below which it is shaped like a cone or funnel, with three channels extending from the base through its sides to the bottom of the cap, which is shaped like the trefoil. Externally, the cap presents three equidistant wings, that afford a convenient means of applying a correspondingly shaped wrench to screw it on or off. Within each three-inch tube is placed a one-inch tube that extends up through the apertures in the perforated plate, in which it fits loosely. This arrangement permits an uninterrupted flow of water from the tank through the inner tubes into the caps; from thence upward through the annular spaces between the inner and outer tubes into the tank, and through the perforated plate upward.

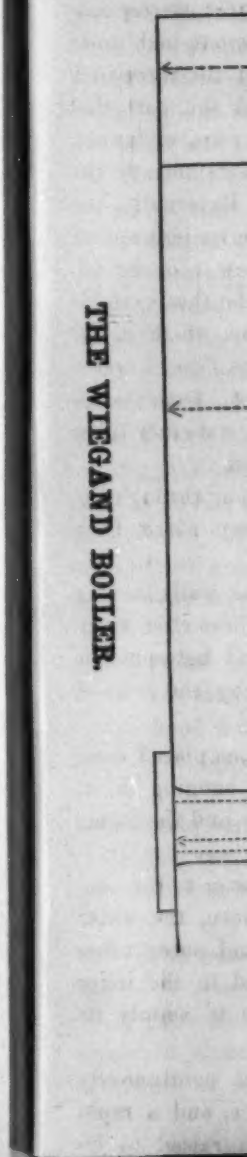
Water is supplied to and blown off from the section through the same orifice in the front end of the tank, and the steam passes from the centre of the tank into the drum.

The furnace is a rectangular chamber with vertical walls, having the usual ash-pit and grate-bars and fire-doors. The heat rises vertically between and around the tubes, also around and between the tanks, and around the bottom of the drum, whereby the heat is equally distributed.

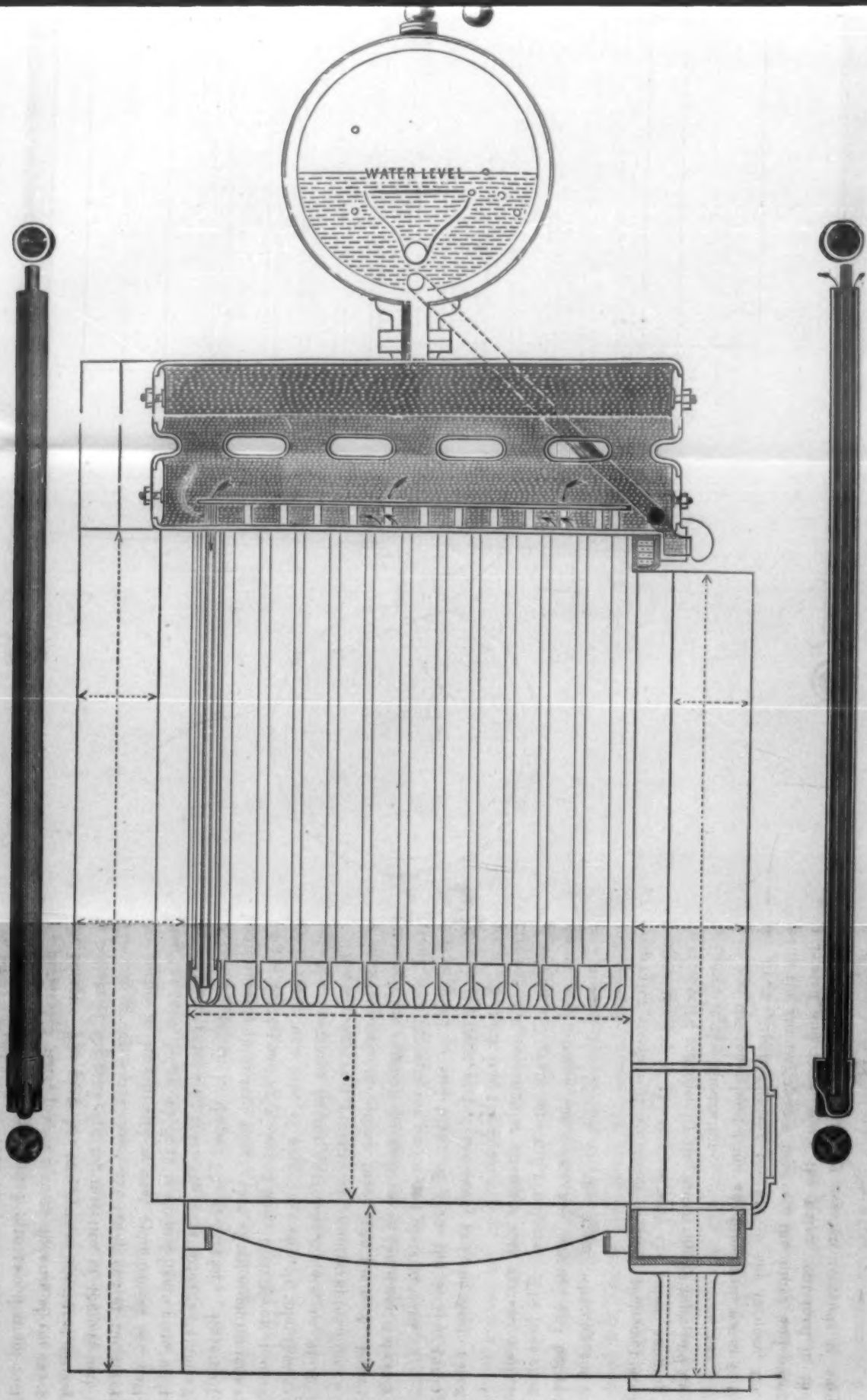
The Generator consists of a number of these sections placed close together upon the top of the furnace with the tubes hanging in it. They are connected together by the water-supply pipe and the steam drum, as shown in the illustration.

When in use, the tanks and drum are filled with water to the centre of the drum; upon lighting the fire in the furnace, the water contained in the annular spaces between the inner and outer tubes becomes heated and rises, while the water contained in the inner tubes, being cooler and specifically heavier, descends to supply its place.

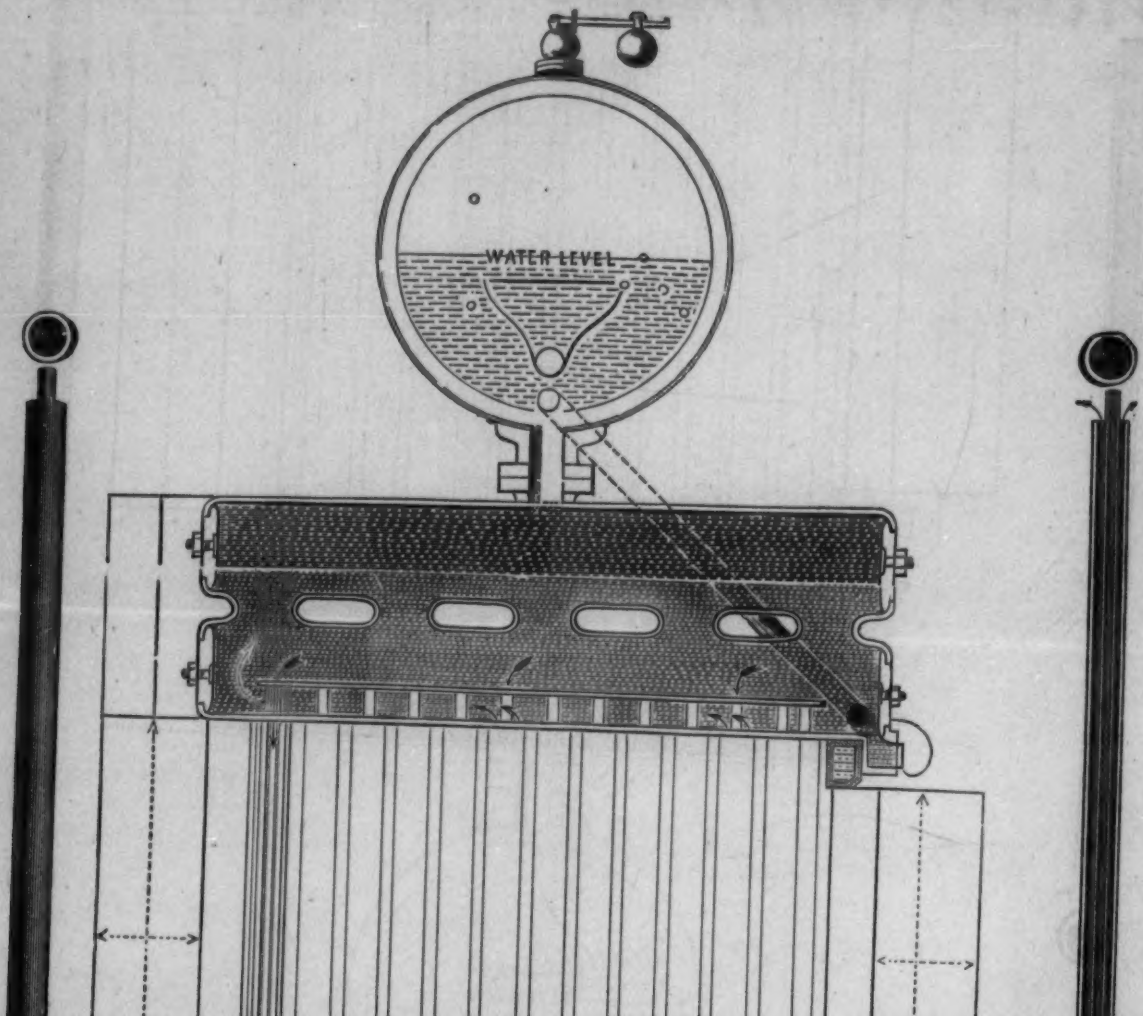
Thus all the water contained in the Generator is continuously brought into intimate contact with the heating surface, and a rapid generation of steam is the result. Steam has been raised to 80

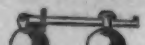


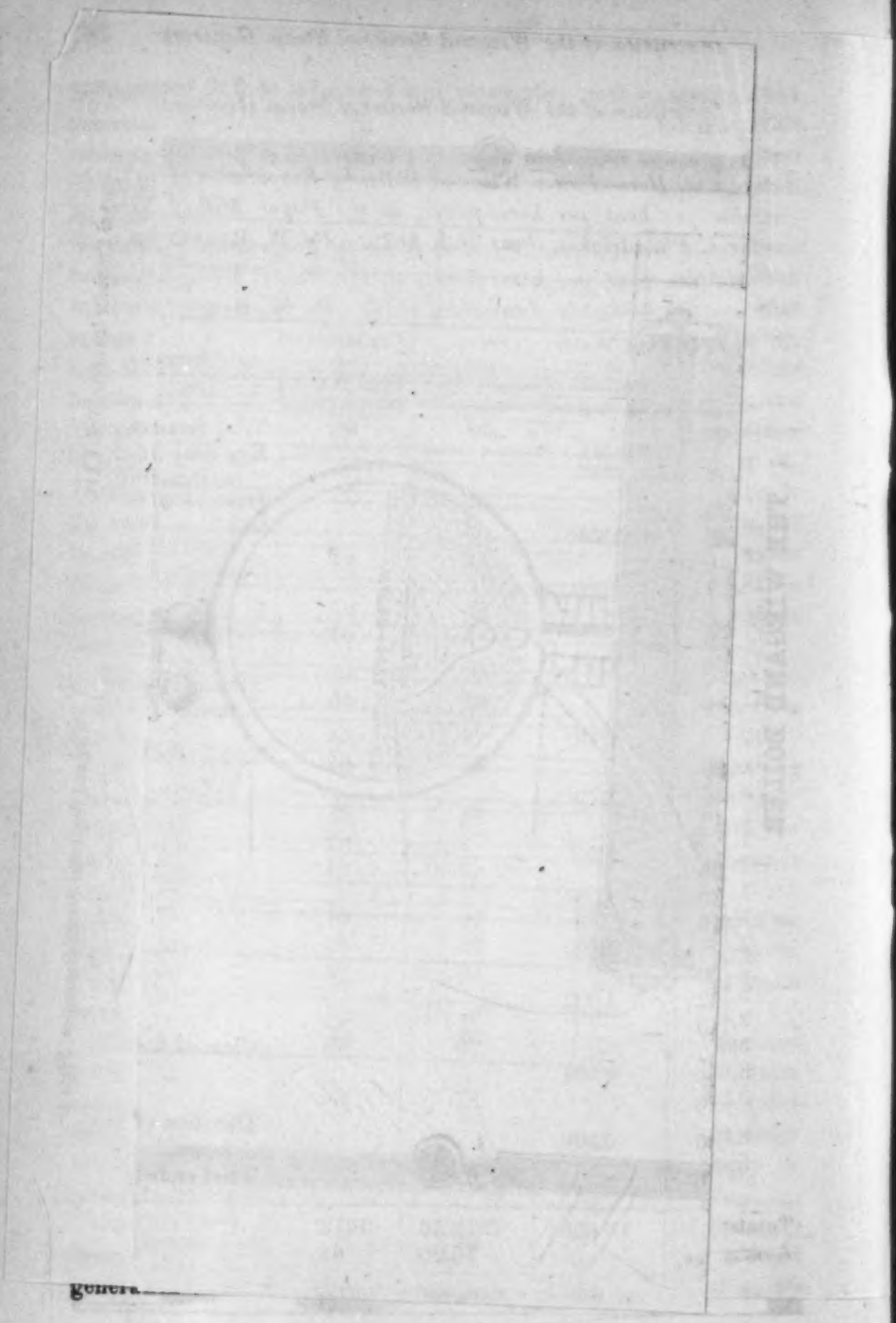
THE WIEGAND BOILER.



THE WIEGAND BOILER


WATER LEVEL





pounds pressure from cold water in a Generator of 320 horse-power in 20 minutes.

Test of a 60 Horse-Power Wiegand Boiler by Evaporation of 900 cubic inches per hour per horse-power, at the Paper Mill of Nixon & Stokes, Philadelphia, June 28th, 1872. By W. BARNET LE VAN, *Engineer.*

Hour.	Feed Water in Pounds.	Steam per Square Inch.	Temperature of Feed Water.	Remarks.
9.40		78	62	Trial commenced.
9.58	1300			Egg coal, 1620 lbs. (anthracite).
10.20		68	62	Damper wide open.
10.33	1300			
10.40		82	62	
10.57	1300			
11.		85	63	
11.20		80	64	
11.30	1300			
11.40		85	65	Steam blowing off free.
12.	1300	78	64	
12.20		78	65	
12.30	1300			
12.40		84	65	
1.	1300	72	62	
1.20		62.50	64	
1.30	1300			
1.40		70	64	
2.	1300	78	64	
2.20		66	62	
2.32	1300			
2.40		77	62	
3.		79	63	Cleaned fires.
3.06	1300			
3.20		81	60	
3.30	1300			Duration of trial 6 hours.
3.40		69		Trial ended.
Totals,	15,600	1372.50	1073	
Averages,		76.25	63	

Results of the Trial.

Grate surface,	22.66
Heating "	812.
Ratio of heating surface to grate surface,	35.87
Coal in pounds,	1,620
Feed-water in pounds,	15,600
Temperature feed-water, Fahrenheit,	63°
Pounds of water evaporated per lb. of coal,	9.63
" " per sq. ft. of grate surface, per hour,	114.7
" " per sq. foot of heating surface per hour	3.20
Equivalent evaporation of water at 212° Fahrenheit, and atmospheric pressure,	18,468
Pounds of water evaporated per lb. of coal, 212° Fahrenheit,	11.40
Square feet of heating surface required to evaporate one cubic foot of water per hour,	12.99
Pounds of coal per square foot grate surface, per hour,	11.47

Recapitulation.

Feed-water in cubic inches per hour, 63° Fahrenheit,	72,020
" " " 212° "	85,260
Horse-power per 900 cubic inches per hour, 63° Fahr.,	80
" " " 212° "	94.93

NOTE.—To make the proper correction for 212°, and to ascertain the quantity of water which would have been evaporated had the feed-water been at 212°, the following rule was used in the calculation:

Latent Heat of Steam.		Total Temperature of Steam in Boiler.		Degrees of Feed-water.		Pounds of Water per Hour.		
966.6	:	1208	—	63	::	2600	=	3078

A Tunnel under the Gibraltar Straits.—It is said that the Spanish Government has under consideration a plan for constructing a tunnel under the Straits of Gibraltar, which, if carried out, would bring this country into close connection with India.

The length of the tunnel would be 13,800 metres, while that across the English Channel at the Strait of Dover is given at 32,000 metres.

Chemistry, Physics, Technology, etc.

SPECTROSCOPIC NOTES.

The Method of Ascertaining the Velocity of a Luminous Body by the Displacement of Lines in its Spectrum.

By Prof. C. A. Young, Ph. D., of Dartmouth College.

The great interest excited by the late researches of Mr. Huggins upon the motions of the stars as indicated by the spectroscope, leads me to think that some of the readers of the "Journal" may like to see the method by which the calculation is made, a little more fully explained than they will find it in the popular periodicals.

When a ray of light strikes the refracting surface of a prism, the direction it will take after refraction depends upon the angle at which it strikes, and also upon the number of pulsations that reach the surface per second; anything which changes this latter factor, the *pitch* of the light, to speak after the analogy of sound, will alter the direction of the ray.

If the source of light and the prism are at rest, then the number of pulses reaching the prism each second will be the same as the actual number of vibrations performed by the molecules of the luminous body. If they, either or both, have any motion towards or from each other, this will no longer be the case, but the number of pulses which reach the prism will be increased or diminished, and in consequence a ray whose wave length is λ, will be altered in its direction, and instead of coming to its normal position in the spectrum will be displaced.

Suppose now the prism, P, and the luminous body, L, to be at rest,

and that N represents the number of vibrations executed by L and reaching P each second. Calling the velocity of the ray V, and its wave length λ, we have, from the general principles of wave motion, $N = \frac{V}{\lambda}$ (1);

hence also, of course, $\lambda = \frac{V}{N}$ (1′)

Next suppose that each second the prism is transported towards L a distance, P P′, which we will call S; or, what comes to the same thing (since it makes no difference *how* P and L are made to diminish

their distance, whether by the motion of P, or of L, or both), let P and L approach each other with a velocity, S.

Putting M to represent the number of pulses per second now encountered by the prism, M must exceed N by the number of waves in P P′, *i. e.*, by $\frac{S}{\lambda}$

Hence $M = N + \frac{S}{\lambda}$, or replacing N by its value from (1), $M = \frac{V + S}{\lambda}$ (2).

Under normal circumstances, a ray making M impulses per second upon the prism would have a wave length found according to formula (1′), by dividing V, the velocity of light, by M. Calling this wave length λ', we have $\lambda' = \frac{V}{M}$, or, putting for M its value from equation (2), we get $\lambda' = \lambda \left(\frac{V}{V + S}\right)$ (3).

Now, since the direction the incident ray will take, depends upon the number of impulses per second upon the prism, it follows that the ray whose wave length is really λ, will be caused by the supposed motion to take the same path as would be followed by a ray whose wave length under normal circumstances is λ'; in other words, its wave length has been virtually changed from λ to λ'.

Formula (3) enables us to compute the amount of this change of wave length due to a given velocity, S.

The problem, however, is more commonly the inverse one, from a given displacement to deduce the velocity that produced it. It is solved, of course, by simply finding the value of S from equation (3). It gives us $S = V\left(\frac{\lambda - \lambda'}{\lambda'}\right)$ (4), which is the formula employed by Huggins in calculating the motions of the stars, the quantity $(\lambda - \lambda')$ being determined by observing the displacement of some dark line in the spectrum of the star under investigation; the hydrogen lines are most commonly employed.

I annex a short table, showing what velocities would be required to produce a displacement of one unit of Angström's or Kirchoff's scales for each of the principal Fraunhofer lines. On Angström's scale each unit corresponds to a change of one ten millionth of a millimetre in the wave length. Kirchoff's scale is arbitrary and somewhat irregular, but is easily referred to Angström's:

	C	D_2	E	F	$H\gamma$ (near G)	H
	miles per sec.					
Ang.	28·27	31·57	35·21	38·16	42·75	46·75
K.	79·90	46·04	28·19	28·34	24·02	15·87

The irregularity noticeable in the lower line at F is not an error of computation, but is due to the irregularity of Kirchoff's scale. The velocity of light has been assumed as 185,500 miles per second.

It is worthy of notice that since this velocity of light enters into the computation, any difference in the velocity of red light and blue light through the celestial spaces, would cause these numbers to vary, and it has been proposed by more than one to test the question whether all rays really have the same velocity in the interplanetary spaces, by measuring the displacement of different lines in the spectrum of a heavenly body moving rapidly towards or from us.

It is easily shown, however, that with our present instruments this is impracticable; the total displacements themselves are so small and difficult to measure that no conclusions could safely be founded on minute discrepancies in the observations.

EXPERIMENTS ON HEAT, RADIATION, &c.*

Heat is generally considered by physicists to be a sort of motion of the particles of matter, and a heated body is said to cool when it transmits that motion to the particles of a contiguous body. But a heated mass will also cool if placed in the receiver of an air-pump, and it is generally believed that it would lose its heat even in absolute vacuum, isolated from all material communication with surrounding masses. This latter process is called the loss of heat by radiation.

I believe that the common ideas of radiation are correctly expressed in the following statements:

That heat passes in straight lines into space from the surfaces of all bodies, at all temperatures; that of two small bodies, in space, each receives from the other that proportion of the whole heat radiated which its projection on the surface of a sphere, with radius equal to the distance between the bodies, bears to the whole surface of that sphere.

That of two similar bodies in space, with different temperatures, the body which possesses the highest temperature radiates its heat more rapidly than the other.

* The Editor desires the Author's name.

That the interstellar spaces are occupied by an ether or medium of some kind, through which heat is transmitted from point to point in space.

That this medium acts simply as a carrier, and in no case as a source of heat.

To test, if possible, the correctness of these statements, I undertook a series of experiments, the results of which form the subject of this paper.

On a clear, still night, and in a position where there was a field for free radiation for ninety degrees, on every side of a vertical line, I placed a spherical mirror with its concave surface upwards; a thermometer in the focus showed a temperature five degrees lower than that of the surrounding air. In the axis of the mirror, and six feet above the focus, I placed a vessel containing a freezing mixture; the thermometer showed no appreciable downward tendency. I then placed a second mirror, with its concave surface downwards, and having the freezing mixture in its focus; the temperature of the thermometer fell two degrees.

Here it will be noticed that, in the first part of the experiment, where the thermometer radiated freely into space, receiving no heat except from its contact with the air and from the radiation of the lower mirror, it showed a higher temperature than at the close of the experiment, when it received, in addition, the heat radiated from the upper mirror and from the freezing mixture.

It might be urged that the radiation from stellar and planetary masses was greater than that from the freezing mixture. If this be so, then their radiation could be represented by the radiation of a firmament having a temperature between that of the air and the freezing mixture. Such temperature must, of course, be supposed constant; but by performing the experiment in air at different temperatures, varying limits for the temperature of the firmament, and limits which contain no temperature in common, were arrived at. There was evidently, then, something wrong, either in the law of radiation or in the manner of conducting the experiments.

As a check upon the foregoing, and as a means of ascertaining the relative quantities of heat which a body, cooling in air, lost by convection and by radiation, I prepared two copper cylinders, ten inches in diameter and two inches deep. These were filled with hot water and suspended in the open air; the temperature, both of the air and water, being recorded at the moment of suspension and half

an hour afterwards. Subjoined is a tabulated record of a number of these experiments:

Initial Temperature.		Temperature after half an hour's exposure.	
Water.	Air.	Water.	Air.
144° F.	83° F.	131·9° F.	83° F.
126 "	83 "	117·4 "	82·8 "
145 "	70 "	129·7 "	70 "
140 "	65 "	124·3 "	65 "
135 "	29 "	110·0 "	29 "
122 "	27·5 "	101 "	27·1 "
75 "	25 "	65 "	25 "
145 "	2 "	106·5 "	1·6 "
50 "	—0·5 "	39·3 "	—0·6 "
42·2 "	—0·5 "	33·1 "	—0·6 "
100 "	—6 "	74·2 "	—6·1 "
145 "	—10 "	103·8 "	—10 "
65 "	—10 "	48·7 "	—10 "
145 "	—13·5 "	102·3 "	—13·8 "

Now, giving a certain initial difference of temperature between the water and the air, and leaving out of the question any radiation from the firmament to the flask, the higher the absolute temperature of the water at starting, the greater should be the amount of heat radiated in a definite time. Such was not the case. The flask at 65°, with air at —10°, lost in the same time a greater number of degrees than the flask at 140° with air at 65°; the greater loss in the former case being due, probably, to the increased density and consequent increased convective capacity of the air.

Ignoring altogether the law of radiation, and assuming if μ represent the loss in degrees per minute for a difference of 1° F. between the vessel and the air, that $\mu x^{\frac{4}{3}}$ will represent the loss in degrees per minute for a difference of $x°$. We deduce at once the formula

$$d_2 = \frac{27\, d_1}{\left(3 + \mu t\, d_1^{\frac{1}{3}}\right)^3}$$

Where d_1 represents the initial difference in degrees between the air and the water, and d_2 the difference in degrees after exposure for the time t. For one pound of water with one square foot of smooth copper surface, μ would equal ·0085. In my experiments with (7 lbs.

water + 1·969 lbs. copper vessel) equivalent to 7·15 lbs. water, and 244 square inches surface, $\mu = \cdot 002$.

The above formula gave results agreeing very closely with experiments performed in a still atmosphere.

Again, I blackened one face of each cylinder, and suspended them about one and one-half inches apart, with the blackened surfaces turned towards each other. They were then filled with hot water, and the temperatures of both air and water recorded; a third flask, similar in every respect to the preceding, and filled with water at the same temperature, was suspended at the same time; the temperature fell uniformly in all three flasks, and at the end of half an hour a sensitive thermometer indicated the same temperature in all. In this case, the blackened face of each of the connected flasks intercepted more than one-sixth of the total heat radiated from its neighbor; the large angle of the incident rays and the rough nature of the opposing surfaces precluding the idea of any considerable portion of the heat being lost by reflection; yet the single exposed flask, which should have radiated one-sixth more heat in the time, possessed the same final temperatures as the others.

This experiment I repeated under a variety of circumstances, connecting the flasks two and two, and exposing the remaining one separately through their different combinations. The results convinced me that if any heat were lost by radiation, it was too small in quantity to be appreciable by the instruments used, and certainly far too small to perform the functions which modern physics assigns to radiation.

The experiments of Wells, in his investigations concerning the formation of dew, seem almost to demonstrate the theory of radiation.

The ice beds of India, where ice is formed by simply opposing to a tropical sky the surface of a thin stratum of water, add strength to the evidence. But the fact that, though the earth appears to draw an immense and continuous supply of heat from the sun, its average temperature remains unchanged, would seem almost to necessitate the assumption of loss of heat by radiation.

In the course of his experiments, Dr. Wells discovered that on a clear, calm night, a thermometer placed just above the surface of the ground indicated a temperature several degrees below that of another placed eight or ten feet above the ground. He also observed that dew formed more copiously on the leaves of plants, on grass, and on the surfaces of rough bodies generally, than on bright metallic sur-

faces or on the face of a beaten road; and that little or no dew was deposited during windy or cloudy nights.

When one of his thermometers, placed among the highest blades of a tuft of grass, had reached its minimum temperature, he interposed a board between grass and sky, and found that the temperature of his thermometer rose rapidly. From these observations, and from the well-known fact that bodies with rough surfaces absorbed and parted with heat more readily than bodies with polished surfaces, he reasoned that, as the air continually abstracts heat from the earth during a summer day, its capacity for moisture must continually increase until a point is reached at which earth and air have the same temperature, and if, after reaching this point, the temperature of the air should, from any cause, be lowered, its superfluous moisture would be deposited in the form of a shower, falling equally on all surfaces, irrespective of form or temperature; but if, from the operation of any cause, one portion of the ground should cool more rapidly than another, and all more rapidly than the air, then would the moisture be distributed unequally, the cooler surface receiving the larger share of dew. The existence of some such cause seemed unquestionable.

Was it the conduction of the earth's surface heat downward? No; for the least moisture was always deposited on the surface of the best conductors.

Was it the convection of the surface heat by the air. No; for in that case the air must always possess the lower temperature. Clearly, then, there was but one solution to the problem, the truth of which all previous experiments seemed to confirm, and that was the free radiation of heat into space. A repetition of Dr. Well's experiments gave me similar results.

I found that a thermometer in the grass indicated a lower temperature than one suspended in the air.

I found that on interposing a door between the lower thermometer and the firmament, its temperature rose; but on substituting for the door a framework arranged lattice-wise, which allowed a free passage to upward currents of air, the temperature was hardly affected, though the framework presented as complete an obstacle to radiation as the door.

A sheet of bright copper foil suspended across two threads, had its upper surface wet with dew, while the lower surface remained dry. Is it possible that the lower surface, a bad absorber, should have maintained a constant temperature of five or perhaps ten degrees higher

than the upper surface, a bad radiator, where the surfaces were not the thousandth of an inch apart, and the material such a perfect conductor as copper?

If one-half the difference had existed between the temperature of the faces, the copper slip would have warped into a curve of less than six inches radius, but no change in its form took place. I blackened first the upper, then the lower, then both faces of the foil, and exposed it in each condition; the result was always the same, moisture was deposited above, while below it remained dry, and its form never changed.

I suspended it directly over the grass, at a point where the thermometer had indicated the lowest temperature. Here it could not be urged that radiation from the earth had warmed the lower surface, yet the result was still the same. The conclusion to which these experiments led me was that whatever might be the cause of its formation, dew existed in the air as moisture, not vapor, at a considerable distance above the surface of the ground, and if it is deposited more copiously on leaves, or grass, or filamentous objects, it is for the same reason that ice or any salt in solution, crystallizes round the same objects as nuclei, in preference to smoother surfaces.

With regard to the ice beds of India. We know that water can be frozen in the receiver of an air pump, by its own vaporization, consequent on the rapid exhaustion of the air. We know that air at all temperatures and under all pressures will hold a certain amount of vapor in suspension, and that the higher the temperature, other things being the same, the greater its capacity for vapor.

The hot, dry air of India acts as a partially exhausted receiver; the flat, porous pans assist the act of evaporation; and the non-conducting nature of the substructure insures that the vapor shall remove the heat more rapidly than the earth can restore it. If radiation were the sole agent in producing the effect, then ice might be formed by similar means, as well, if not better, in England as in India. All attempts to produce ice in this manner, in the moist atmosphere of England, have failed.

With reference to the disposition of the heat received by the earth from the sun, Faraday has stated that the average amount of heat radiated in a summer's day upon each acre of land in the latitude of London is not less than that which would be emitted in the combustion of sixty stacks of coal. Herschel and Pouillet estimate the heat received in one year as sufficient to melt a shell of ice covering the earth's entire surface to a depth of ninety-seven feet. If this immense

quantity of heat is received by the earth yearly, what becomes of it? and in what manner is twenty-three hundred million times the amount returned yearly to the sun?—for, if the law of radiation be true, this amount must be replaced or the temperature of the sun must fall. One hypothesis is that the sun's loss of heat is *not* made good, but that the sun is cooling, and has been for ages. This the facts of history do not confirm, and philosophic observation cover sufficient time to demonstrate its fallacy. Another hypothesis is that the sun's heat is maintained by the chemical combination of its own constituents. This will not bear the test of figures, unless we assume the existence of elements in the sun which will, by their union, develop far more heat than oxygen and hydrogen. But the most generally accepted hypothesis is that the sun's heat is produced and maintained by the falling of meteoric masses on its surface; and it is to this theory that we shall direct our attention. Without entering into the discussion as to why, if the meteoric shower come from regions beyond the limits of the solar system, the earth and the other planets of the system do not receive the proportion due to their spheres of attraction; or why, if the meteorites existed in the sphere belted by the earth's orbit, they have not ages ago been absorbed, we come at once to the question, Would a body, falling into the sun by virtue of the sun's attraction, develop any heat not previously possessed by the sun and the falling body? If the earth, with its present temperature, stood at rest in its orbit to-night, and if, uninfluenced by any cause but the mutual attraction of earth and sun, it started on its course for the sun's centre, would the sun be hotter after the impact than it is at present? The analogy between masses falling into the earth and planets into the sun must furnish the answer. A body, one pound in weight, falling from a height of 772 feet, would acquire a velocity of 222 feet per second, and develop, on striking the earth, sufficient heat to raise a pound of water 1° F. Now, whether this body move horizontally or vertically, whether it move under the influence of gravity or any other force, so long as it possesses that velocity at the moment of impact, the same amount of heat will be generated.

I have seen a three hundred pound shot brought suddenly to rest against the face of an iron target, and the heat developed by the concussion such that the unprotected hand could not endure it. If the motion of this projectile, instead of being arrested instantly, had been taken up gradually by an elastic cushion, or by a continuous graze the same amount of heat would have been generated, part in the shot and part in the retarding medium.

Now, in what respect does a shot, fired vertically and retarded by the force of gravity, differ from a shot fired in any other direction and retarded by any other force? In every other case, where the velocity of a body is destroyed, heat proportional to that velocity is generated; where velocity is acquired, heat or its equivalent motion is lost in producing it.

It seemed to me reasonable that the same thing should occur in the case of a body moved or retarded by the force of gravity. I thought that if a thermometer, with a self-registering arrangement, should be attached to an arrow and shot upward, it would indicate a steadily increasing temperature until it came to rest, and on its return a steadily decreasing temperature until it struck the ground. The difficulty of performing such an experiment led me to adopt a modification, of which the details are annexed.

I prepared a thermometer with a bulb $2\frac{1}{2}$ inches in diameter and a stem 5 inches long, and $\frac{1}{10}$ inch interior diameter. The tube was left open at the top, and the glass there was drawn out until it formed a funnel about $\frac{3}{4}$ inch wide and $\frac{3}{4}$ inch deep. This, after breaking a number of bulbs, I succeeded in filling with mercury. The thermometer was then placed in a strong brass box, and the space between the sides of the box and the bulb packed with saw-dust.

A brass lid, with an aperture sufficiently wide to clear the funnel, was slipped along the tube and tightly screwed into the box, leaving about four inches of the stem projecting outside the lid.

When this box was placed in a vessel of boiling water or in a pail of ice, it required twenty-five or thirty seconds to affect the mercury in the slightest degree; but when the temperature of the mercury had risen or fallen even the twentieth of a degree, its motion in the tube was quite perceptible.

I proposed to drop this box from the top of a high building, immediately after having filled the funnel with melted sealing wax. If any diminution of temperature took place during the descent, the wax, from the pressure of the air, would follow the mercury down the tube, and the depth to which it penetrated, supposing the tube to be found unbroken, would indicate approximately the loss of temperature sustained by the mercury while falling. Through the kindness of Mr. Blatchford, the shot tower at Chicago was placed at my disposal.

The clear fall in the interior of the tower is 195 feet. A weight of one pound falling through that distance would, on impact, develop heat sufficient to raise the temperature of a pound of water a little

more than one-quarter of a degree Fahr., or to raise the temperature of a pound of mercury 7¼° Fahr. Now, I supposed that the mercury, in falling through that distance, would lose, by the conversion of its molecular motion into motion of its mass towards the earth's centre, sufficient heat to lower its temperature 3¾° F.; and that the earth, by its motion towards the mercury, would lose sufficient heat to lower the temperature of the same weight of mercury the same number of degrees. A difference of temperature of 3¾° would be represented on the scale of my thermometer by a difference in level of the mercury of 8¾ inches, and at that distance below the bottom of the funnel I made a scratch on the side of the tube.

We suspended the box containing our thermometer in a sort of wire cage, which in its turn was sustained by a single string passing above a rafter in the highest available point of the shot tower, and directly over a water tank 195 feet below.

The mercury was continually removed from the funnel until a period arrived during which it stood steadily at the top of the tube. We quickly filled the funnel with melted sealing wax and cut the string. The thermometer was, of course, broken in fragments by the shock, but the funnel with two inches of the stem attached was afterward recovered, and the wax filled it through its entire length.

It was suggested by one of the gentlemen present that the wax might have been driven into the tube by the concussion, but on performing the experiment with a thermometer having a bulb of the same size, and a tube of $\frac{1}{10}$ inch internal diameter, the wax penetrated to a depth but little exceeding ¾ of an inch; while still another experiment, where the thermometer had a 2-inch bulb and one-tenth inch tube, gave a penetration of the wax of less than ¼ of an inch. If the effect were due to concussion, the greater the diameter of the tube the further should the wax be driven. Precisely the reverse was the case. I had, moreover, previous to the experiments, marked on the side of each of these tubes the depth to which, according to my hypothesis, the wax should be driven, and the results were such as to place that hypothesis almost beyond a doubt.

That a body should cool by the mere act of falling would seem at first sight to conflict with the circumstances of our every-day experience; but when these circumstances are carefully examined the difficulty vanishes, and the necessity for some change in the state of the falling body other than simple change of position in space becomes apparent.

(To be continued.)